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The geological development of Ohio; F. Carney. 15 pp.
The relief features of Ohio; F. Carney. 13 pp., 1 fig.
Geographic conditions in the early history of the Ohio country; F. Carney. 20 pp.

DENISON SCIENTIFIC ASSOCIATION

Organized April 16, 1887

REPORT OF THE PERMANENT SECRETARY FOR THE YEAR 1930–1931

During the college year 1930–1931 the following officers served the Association.

L. E. SMITH, *President*
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In accordance with the usual procedure, the Association held its meetings on alternate Tuesday evenings throughout the year; the other Tuesday evenings were given up to meetings of the students' departmental societies. Speakers and their subjects at our meetings were as follows:

September

GOLD AND BANKING PROBLEMS—H. L. JOME

October

SPACE PERCEPTION IN A HORIZONTAL PLANE—W. L. SHARP (Wooster)
WHAT IS LIFE?—A. W. LINDSEY

November

MEASURING MOLECULES—W. A. EVERHART
PUBLIC SPEAKING AS APPLIED PSYCHOLOGY—L. G. CROCKER

December

NUMBER—F. B. WILEY

January

PRACTICAL USE OF TRANSPORTATION SURVEYS—B. D. GREENSHIELDS

February

SPACE, TIME AND RELATIVITY—PAUL BIEFELD
PAYING TAXES TO THE SEA—H. S. SHARP
THE WORLD'S MOST FAMOUS GARDENS—M. E. STICKNEY

March

MYSTERIES—L. R. DEAN

April

YELLOWSTONE NATIONAL PARK—G. D. MORGAN
APPLICATION OF BIOCHEMICAL RESEARCH TO THE CHANGING OF HUMAN NATURE—J. B. BROWN (Ohio State University)

May

THE RACE CONFLICT IN SOUTH AFRICA—F. G. DETWEILER
VERDUN FORTS—H. A. DE WEERD

Two numbers of the JOURNAL OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY appeared; their contents follow:

Vol. XXV, Articles 6–7, pp. 201–299, December, 1930.
The Actinoceroids of East-Central North America; Aug. F. Foerste and Curt Teichert. 96 pp., 33 plates.
The Presence of Nybyoceras in South Manchuria; Riuji Endo. 3 pp., 1 plate.
Vol. XXVI, Article 1, pp. 1–142, April, 1931.
The Hesperioidea of North America; A. W. Lindsey, E. L. Bell and R. C. Williams, Jr. 142 pp., 33 plates.

The Association regrets to announce that the unfortunate financial situation of the present day has resulted in a sharp reduction of the appropriation made by the Trustees of Denison

University for the publication of its JOURNAL OF THE SCIENTIFIC LABORATORIES. The output of papers during the coming year must therefore be limited. We trust that the various scientific institutions, libraries, universities and private subscribers receiving the JOURNAL will excuse the smaller size of our annual volume.

In closing, the Permanent Secretary takes this opportunity to thank his colleagues, Drs. F. J. Wright and A. W. Lindsey, for their work in supervising the publication of the two numbers of the JOURNAL referred to earlier in this report. The absence of the Permanent Secretary, due to his residence in Istanbul, Turkey, during part of the year, made it necessary to provide thus for the prompt appearance of the JOURNAL. Let those two numbers of the JOURNAL attest to the skill and care of these two friends!

Respectfully submitted,

W. C. EBAUGH, *Permanent Secretary*

THE OLDER APPALACHIANS OF THE SOUTH

FRANK J. WRIGHT

Received October 28, 1931; published January 15, 1932

AWARDED THE A. CRESSY MORRISON PRIZE IN NATURAL SCIENCE FOR 1931
BY THE NEW YORK ACADEMY OF SCIENCES

CONTENTS

Introduction

As the traveler from the eastern seaboard starts upon his westward journey, he traverses the level plains of the Atlantic Coast and the rolling topography of the Piedmont until he approaches the easternmost member or the Appalachian Mountain chain. Shrouded in a haze of blue he sees the uneven and irregular form of a complex mountain, marked, in some places, by sprawling spurs and subordinate, rambling ridges, and in others by a steep eastward-facing, moderately dissected scarp. This is the Blue Ridge. It stretches from southern Pennsylvania to northwestern Georgia, and constitutes the first topographic barrier to the westward movement of the population.

The valley of Roanoke River at Roanoke, Virginia, divides the Older Appalachians[1] into two parts, the one extending to the northeast and the other to the southwest. The northern division is nowhere more than ten to twenty miles wide and is made up in places of several subordinate ridges grouped about a central higher one, while in other places there is only a single ridge with sprawling spurs. It is broken by water gaps, such as the James and the Potomac, and by wind gaps, of which Manassas Gap is one of the deepest. The southern division is much broader, attaining a width of eighty miles in the Asheville region. It is not pierced by through-flowing streams. It is a mountainous upland sharply limited on the west by resistant sandstone and quartzite ridges, and on the east by a steep escarpment called the Blue Ridge.

The massive ranges and high peaks of the Older Appalachians south of Virginia contrast with the lower elevations and less majestic forms of the northern district. Mt. Mitchell (6684′), and other closely associated peaks, rise slightly above the bold form of the Black Mountains. Grandfather Mountain (5964′) stands on the very edge of the Blue Ridge escarpment.

[1] "Older Appalachians," as used in this paper, is the equivalent of the Blue Ridge Province of Fenneman (29). The Blue Ridge Mountain forms only a small part of the Province, and is a localized and special feature which is not typical of the Province as a whole. If the term Blue Ridge Province were used in the text, it might be difficult to avoid confusing it with the Blue Ridge scarp.

The Smoky Mountain group in eastern Tennessee and western North Carolina forms a most imposing skyline with many points above 6000 feet in elevation. The peaks along this range are not conspicuous because they rise but slightly above the level of the mountain mass.

From a topographic standpoint the Older Appalachians of the South are an elevated and isolated mountain group bordered by the Appalachian Valley on the northwest, and by the Piedmont on the southeast. The Piedmont is a lowland with reference to the Blue Ridge and in its erosional history it has much in common with the Valley on the opposite side. In fact, as will appear later, the Valley and Piedmont erosion surfaces extend up into the mountains in the form of mature valleys and even local peneplanes.

The writer desires to acknowledge his deep indebtedness to his former teacher, Professor Douglas Johnson of Columbia University, whose suggestion was responsible for the beginning of these studies in 1923, and whose generous later assistance, including two brief visits to the field, has been of great value. Advice has also been graciously given by Professor William M. Davis. The writer was accompanied and assisted in the field at different times by four of his former students, L. C. Miller, Harlan Yoakam, Otis Curtin, and Homer Eddy. Professor Henry S. Sharp, a colleague at Denison, has read the manuscript and offered timely suggestions. The author, of course, assumes full responsibility for the opinions and conclusions herein expressed. Field work was carried on with the aid of a grant of money from the Esther Hermann Research Fund of the New York Academy of Sciences.

Although the intent of this paper is to deal with the erosional history of the Older Appalachians and especially the Blue Ridge, it was found desirable to carry the study westward into the Newer Appalachians and on into the Appalachian Plateau. In these last-named areas the work was done rapidly with the idea of correlating the erosion surfaces of all the Appalachian provinces. It is now believed that the work has gone far enough to set

up a working hypothesis not only for the crystalline areas but also for the entire region of the Southern Appalachians.

As will appear in subsequent paragraphs much of what is said here rests upon the strong foundation of descriptions and interpretations already given by Keith, Campbell, Hayes, Davis, Johnson, Willis, and others. It is the hope of the present writer to correlate correctly the elements of the topography of the different areas and to assign each group its proper place in the history of the region.

Summary of Erosional History

At the outset it might be well to outline the history as understood by the writer and to indicate the points of essential divergence from the commonly accepted history.

The oldest erosion surface that is preserved well enough to be restored is the Upland or Schooley[2] Peneplane. Certain mountain groups, such as the Great Smokies, the Tennessee Ridge, and the Black Mountains, rise 2000 feet or more above the well-developed Schooley level in nearby areas, and may represent the dissected remnants of the Fall Zone Peneplane described in the writings of Johnson and Sharp. The Schooley Peneplane was uplifted and thoroughly dissected, and is restored with difficulty except in a few localities. The second cycle that has left an unquestioned record may be correlated with the Harrisburg of the Northern Appalachians and has given us many of the features of the region. Its stamp appears almost everywhere except in those massive monadnock areas referred to above. It was during this cycle that the present upland surfaces of the Piedmont and the Great Valley were developed, and in addition scores of extensions of these surfaces in the nature of former mature valleys and even local peneplanes which attain elevations of 2000, 3000 and even 4000 feet in the higher parts of the mountains. The Asheville basin is perhaps the best example of these local peneplanes. The record of this cycle can be traced along the New River from its head, near the base of Grandfather Mountain, out through the crystallines, across the Great Valley and the Allegheny Ridges, and into the Plateau, where it apparently forms the upland surface some distance west of the scarp. During this cycle were developed the meanders of the Kentucky and Cumberland Rivers in the Highland Rim and Lexington Plain areas of Kentucky and those of the New River in three great physiographic provinces, as well as those of scores of other streams south of the Potomac. These meanders are now intrenched because of the uplift which inaugurated the present

[2] The terms Upland and Schooley are preferred rather than Cretaceous, which commits us to a specific date of origin that is not yet settled. In like manner Valley and Harrisburg, equivalents of Tertiary, are employed in this paper.

cycle. It is an open question whether we should consider the very local level which appears just above the present floodplains in areas of extremely soft rocks—and frequently at the junctions of master streams—as the work of a distinct cycle, or partial cycle, or rather as an episode in the present cycle. The name Somerville has been assigned to this surface in New Jersey, Worthington in Pennsylvania, and Coosa in southern Tennessee and Alabama.

In the above outline there is nothing essentially new. It does assign vastly more importance than formerly to the second or Harrisburg cycle of erosion in the interpretation of the topography. The Blue Ridge scarp maintains for the most part the Schooley Peneplane level but in some places its crest preserves the Harrisburg. This occurs where it has retreated far enough to intersect the surface of a high-lying local basin. Perhaps the most original idea in the present paper is the tracing of the Harrisburg surface from broad low-lying areas underlain by weak rock up to high-lying local basins underlain by rocks of moderate resistance and held up by resistant rock barriers across the streams. It furthermore brings out the interesting relationship between two erosion surfaces where the lower one rises locally up to within several hundred feet of the higher regional surface near the heads of the streams. This is illustrated in the crystalline area and in the Appalachian Plateau just west of the scarp. This aspect of the present interpretation contrasts sharply with the early views of Keith (48), who placed in four different cycles the erosion remnants which are here referred to one.

A further corollary of the present hypothesis is that uniformity of elevation above sea level of different parts of a supposed erosion surface is not necessarily proof that the detached remnants belong to one and the same cycle, nor does diversity in elevation preclude their formation at the same time. Three great factors, first suggested by Davis (27), determine largely the altitude of Harrisburg remnants in the Southern Appalachians. These are rock resistance, presence of rocky barriers across streams, and distance to the sea. These factors cause the

Harrisburg in some places to stand higher than the Schooley at others, and produces the great diversity of over 3000 feet among the remnants of Valley cycle erosion.

The present interpretation, if correct, would unify and simplify the history of the Southern Appalachians and help in tracing the drainage changes along the scarp and elsewhere in the area.

History of the Older Appalachians

Monadnocks on the Schooley (Upland) Peneplane

The oldest element in the topography is the various ranges and peaks rising appreciably above the level of the Upland (Schooley) Peneplane, which is to be described in later paragraphs. Profiles, covering alternating belts of country two or three miles wide, have been made for the entire southern portion of the Older Appalachians. An examination of these profiles does not reveal any positive evidence of an erosion surface higher than the Schooley among these groups. Willis (77) has interpreted the high balds of the Great Smokies and Unakas as remnants of an earlier peneplane. "The consequent topography of the earliest Appalachian uplift was entirely removed during a prolonged period of erosion and was replaced by a relief of differential degradation. The balds of the Unakas represent the heights of that first-known approach to a base-level."

As one examines these massive ridges in the field he is impressed with the eveness of the skyline as it appears from certain viewpoints. This is especially true of the central range of the Great Smoky Mountains as seen in Plate XXXIV.

There are at least three possible interpretations for these features. They may represent: (1) a greatly uparched portion of the Schooley Peneplane, (2) monadnocks on that surface, or (3) remnants of an older level or levels.

It should be pointed out that there is a wide range of elevation among these groups. In the skyline in Plate XXXIV, the peaks such as, Clingmans Dome, reach altitudes of more than 6600 feet while the crestline for considerable distances in the same region is below 6000 feet.

A typical area for the study of these features is in the eastern portion of the Smoky Mountains and the region adjacent on the southeast. Balsam Mountain leads southeast from Mt. Guyot, a high point on the central ridge of the Great Smoky Mountains, and connects with Plott Balsams, culminating in Waterrock Knob at an altitude of 6400 feet. Southeast of this locality the crest sags and is marked by Balsam Gap (3316′). It rapidly rises again along the Haywood-Jackson County line to 5865

feet in Steestachee Bald and continues across the northeast corner of the Cowee, North Carolina, quadrangle, at approximately the same elevation, to unite with the northward trending Tennessee Ridge on the western margin of the Pisgah, North Carolina quadrange. This junction is marked by Black Mountain (6275′) and Tennessee Bald (5622′). Pisgah Ridge which extends northeast from this point for about twenty miles has peaks with the following elevations 5816, 6040, 5150, 5450, 5840, 5339, and finally 5749 feet, in Big Pisgah Mountain. Here the main ridge turns sharply to the northwest and is marked at its highest point by Sugar Top, at 4930 feet, just south of the northern margin of Pisgah quadrangle. It forms the Smathers View Mountain in the southern part of the Asheville quadrangle, and beyond the gap of Hominy Creek it leads northwest as Newfound Mountain to the western margin of the Asheville quadrangle, where it unites with the northeastward extension of the central ridge of the Great Smoky Mountains. The crest of this composite ridge throughout the circuit forms the boundary line of Haywood County, North Carolina.

Just southeast of the Tennessee-Pisgah Ridge in the central part of the Pisgah quadrangle the Schooley level is preserved by many hilltops at an elevation of approximately 3100 feet on both sides of the French Broad River basin. It extends to the southeast as far as the Blue Ridge. The Ridge referred to above, as viewed from points in this area, rises from lower elevations in the southwest to higher peaks in the north. It has all the characteristics of a monadnock feature, rising 1000 to 1500 feet above the well-defined Schooley surface along its southeastern base, as may be seen in Plate XXXVI.

When the Schooley at 3100 feet in the Pisgah area is compared with the apparently even skyline of the Great Smoky Mountains at approximately 6000 feet some 35 or 40 miles to the northwest, it is obvious that the possibility of upwarping of the Schooley to a much higher level in the latter area must be taken into account. A present slope of 70 feet per mile is not as steep as the reported slope of the Rocky Mountain Peneplane.[3]

[3] Davis, W. M. The Colorado Front Range: A study in Physiographic Presentation. Annals Assoc. Am. Geog. 1: 41 (1911).

The Black Mountain group, in which Mt. Mitchell forms the culminating point (Plate XXXVII, lies northeast of Asheville in the Mt. Mitchell quadrangle. It resembles the Tennessee-Pisgah Ridge in that it rises from lower elevations at both ends and attains its maximum height in the middle massive portion. Mt. Mitchell (6684′) is but slightly higher than its neighboring peaks, four of which rise above 6600 feet in elevation.

Grandfather Mountain (5964′), standing on the edge of the Blue Ridge scarp in the Cranberry area, has long been cited as an example of a monadnock above the Schooley Peneplane, which has an elevation of approximately 4000 feet in this area. There appears to be no reason to question the monadnock character of Grandfather Mountain. It is a conical remnant situated on the divide between the headwaters of the Catawba and Watauga Rivers.

A number of other mountain groups to the north and especially to the south of those just described apparently rise above the known remnants of the Schooley and are supposedly monadnocks. The ones described are believed to be typical, and further descriptions would add nothing to the erosional history. The solution of the problem of the origin of these features awaits further study. The author tentatively regards them as monadnocks on the Schooley Peneplane. This interpretation seems to find support in: (1) the great diversity in elevation among the various groups; (2) the longitudinal profiles of the ridges in many cases rise from lower elevations at the ends toward central higher portions; (3) the apparent absence of any trace among them of a level above which monadnock peaks stand out. In fact, the slopes are often quite continuous from the highest peaks to the present valleys. If the Great Smoky range were an uparched area of the Schooley, one would expect to find remnants, in this extremely resistant rock area, comparable to the remnants of the Schooley surface in the central part of the Pisgah quadrangle; (4) very resistant sandstone, quartzite, and quartz schist for the most part underlie these areas while the Schooley and Harrisburg surfaces have been produced in regions underlain by highly feldspathic rocks, limestones and weak schists.

The writer is quite aware that the Schooley Peneplane as developed throughout the Appalachians was the product of a very long cycle or cycles of erosion and that few unreduced areas remain as monadnocks. An apparent exception is found in the White Mountains which stand conspicuously above the New England Peneplane, the northwestern portion of which, at least, is correlated with the Schooley. It is interesting to note that in the southern Virginia portion of the Older Appalachians very few monadnocks rise above the Schooley. Going toward the southwest the peneplane is less and less well developed and the monadnocks more numerous until the massive ranges above described in the Asheville area pretty largely dominate the skyline. Broad outcrops of highly resistant rocks combined with favored location in reference to drainage lines are probably primarily responsible for the extensive, unreduced areas in the Black, Unaka, Pisgah, Great Smoky, and similar mountain groups.

THE SCHOOLEY (UPLAND) CYCLE

General Statement

Whatever may be the correct interpretation of the erosion remnants described in the preceding pages, they are essentially, at present, monadnocks on the Schooley Peneplane. This is true regardless of the cycle from which they date. In general the peneplane is best developed where the monadnocks are few and least developed where they are numerous. This would lead us to expect larger remnants in the northern and far southern parts of the area than in the central part. While this is true, it must also be remembered that conditions favorable to the formation of a peneplane are also favorable to its destruction in the following cycle. So thoroughly has this been done that in some districts all traces of the Schooley surface have apparently been removed, and we find today only the dissected remnants of a locally developed Harrisburg level.

One striking fact has been impressed upon the writer in his study of the Schooley remnants in the crystalline as well as in the sedimentary areas of the Southern Appalachians. Such remnants are not the broad flat expanses of peneplane surface that are sometimes described. With local exceptions the Schooley is preserved only on stream divides. In some areas such as that west of Caesars Head, South Carolina, the hilltops forming the divides are very accordant. Elsewhere the remnants of Schooley erosion are neither accordant nor flat. In districts which usually have been thought of as typical Schooley country, we find mature Harrisburg valleys, in the lower portions of which, at least, the streams have entrenched themselves in the present cycle. These mature valleys leading up to within several hundred feet of the Schooley are typical of the region, and illustrations will be pointed out in connection with the history of the Harrisburg cycle.

Since the preserved record of Schooley erosion is so meager, it is small wonder that various observers have found different erosion levels, and different elevations for the same level. In some places the surface is preserved by a tattered fragment of a low ridge rising higher and higher above the Harrisburg. It

cannot be Harrisburg, but who can say whether it is Schooley, and if Schooley, which part marks the exact level. Strictly speaking, the elevation of any uplifted and dissected peneplane must be determined by the present altitude of the remnants above sea level. All remnants have been reduced to some extent and it is unthinkable that all should have been reduced the same. Especially would this be true in the case of the Schooley which has passed through at least one complete and one partial cycle since its formation. Areas underlain by massive resistant rock formations will most nearly approximate the level which the region had when the uplift was completed.

In a region which contains rocks of so many varying degrees of resistance as the Southern Appalachians, we should expect to find hilltops and ridge crests at every interval of elevation between the Harrisburg surface and the Schooley. When one recalls that the Schooley was by no means a perfect peneplane in this area and that monadnocks rose from a few feet to more than 2000 feet above its surface, it is obvious that any restoration of this surface must be only approximate. Fortunately, in a few critical areas the level seems to have been sufficiently well developed and preserved so as to give us a good impression of the topography existing at the close of this cycle.

The author would digress to point out that in the Folded Appalachians in Virginia, West Virginia, and Tennessee, where ridge crests, even and uneven, are found at practically every elevation above the well-defined Harrisburg of the limestone and shale valleys, it is futile to attempt a very refined restoration of the Schooley surface. In an earlier paper (79) he tried to restore the peneplane, and made a contour map of its restored surface. At the time of its publication, no claim to a high degree of accuracy was made and he is more convinced than ever that in many parts of the Folded Appalachians, northern and southern, where the only remnants are sharp ridge crests, the determination of the present level of the so-called Cretaceous peneplane is susceptible to a possible error of at least several hundred feet.

Extent of Development of the Schooley Peneplane

From Roanoke, Virginia, to the North Carolina line, the Older Appalachians appear to have been peneplaned in the Schooley cycle, with the exception of the mountains which form the northwestern boundary of the province. The imposing Iron Mountains are the largest units in this group and are undoubtedly true monadnocks. Southeast of this range as far as the Blue Ridge scarp the monadnocks are few, and the peneplane before its dissection was remarkably well preserved at approximately 3100 feet above sea level.

In the extreme northwestern corner of North Carolina, the Upland surface is broken by more monadnocks, although it was well-developed in some localities such as around Sparta. In the northern and central parts of the Cranberry quadrangle, there are numerous monadnock ridges, most of which run parallel to the main trend of the mountains. Some of these are Three Top Mountain (5029′), Bluff Mountain (5073′), Bald of Rich Mountain (5369′), and Stone Mountain (4600′). All of the elements in the topography of the Older Appalachians, from the high monadnocks down to the present valleys are found here, and no one seems to predominate.

The southern part of the Cranberry quadrangle includes a strip of the Blue Ridge scarp and the Grandfather Mountain district of the upland. Grandfather Mountain (5964′) is a grand conical residual, standing at the edge of the escarpment. The scarp to the northeast and southwest seems to preserve pretty accurately the Upland level. About eight miles to the northwest, Beech Mountain, an east-west trending monadnock ridge, attains an elevation of 5522 feet. West of Grandfather Mountain, on the Roan Mountain quadrangle, are located the Cane Creek, Iron, Unaka, and Bald Mountains, all of which have peaks more than 5000 feet above sea level. Roan High Knob has its summit at a height of 6313 feet.

The Mt. Mitchell quadrangle also includes a strip of the scarp, bordered on the east by the Catawba lowland, and on the west by a number of high mountain groups separated by high-lying

stream-carved basins. It is thought that the Upland Peneplane may have been reasonably well developed in that portion of the northeastern area of the quadrangle now drained by the North and South Toe Rivers and Crabtree Creek. The tangible evidence in support of this belief is found in the accordant crests to the northeast of Mt. Mithcell. Sevenmile Mountain apparently represents this level for quite a distance at approximately 3700 feet. The scarp itself is about the same, or a little lower, just east of this ridge. The distant skyline formed by two spurs which border the Linville River valley probably preserves the same level. Furthermore, the extensive development of the Harrisburg surface in this area is strong evidence in support of the former presence of an even more extensive Upland surface. In the remainder of the Mt. Mitchell quadrangle the Upland level is difficult to locate. The massive Black Mountains with a dozen peaks above 6000 feet, including Mt. Mitchell at 6684 feet, occupy the middle portion of this map. Of lesser importance are the Green, Cane River, and Bald Mountains to the northwest, and the Great Craggy and Swannanoa Mountains to the southwest.

The mountains north and west of Asheville, as far as Newfound Mountain, show a rather striking accordance which probably represents the Upland level about 3100 feet above tide. Beyond the Newfound Mountains, little trace of the peneplane has been noted, and the slopes of the lofty Great Smokies seem to extend from their highest portions down to the valleys of the present streams without much break.

The upland around Caesars Head, South Carolina, is typical of a narrow strip of territory extending along the scarp entirely across the Pisgah quadrangle. This is the best preserved remnant of the Upland Peneplane seen by the writer south of Asheville. The Tennessee and Pisgah Ridges lie to the west of Caesars Head and beyond them are the Great Smokies. Important mountain groups extend toward the southwest and terminate in the Cohuttas in northern Georgia. Among these may be mentioned the Cowee, Nantahala, Valley River, and Snowbird Mountains.

Southwest of the French Broad basin the residual domes and

ridges dominate the topography. Among them lie a number of well-defined basins which are at present assigned to the Valley cycle.

It will thus be seen that the peneplane is best preserved in the northern and southeastern parts of the province. It seems strange that the only good remnants south of Virginia should lie along, or near, the Blue Ridge scarp which is the Atlantic-Gulf divide. If this is true, the explanation is probably to be found in contrasted rock resistance which permitted the development of a peneplane in the southeastern area while the hard rocks downstream remained as residuals. Furthermore, the less extensive erosion surface downstream may have been destroyed through subsequent erosion while the headwater areas were only moderately dissected.

Local Remnants of the Schooley Peneplane

The Hillsville, Virginia, Area

The Blue Ridge is a striking escarpment rising 1500 feet or more above the Piedmont as it passes across the southern portion of the Hillsville, Virginia-North Carolina, quadrangle. The crestline is quite uniform at an altitude of from 3000 to 3200 feet. At one point, Fisher Peak, the elevation is 3609 feet. This appears to be a monadnock on the Upland surface. The crest of the Blue Ridge in this area is believed to represent, throughout most of its course, a remnant of the Schooley Peneplane. Furthermore, many of the divides between the northwesterly flowing streams preserve this surface. An especially good example is found in the Beamer Knob-Pike Knob divide between Reed Island Creek and Crooked Creek, a photograph of which is reproduced in Plate XXXV. The term "knob" is not very suitable for these features since there are no pronounced peaks or knobs. Beamer Knob reaches an elevation of 3400 feet, while the others are around 3200 feet. Another example of a similar feature is found between Crooked and Chestnut Creeks.

Traces of the level are also found in other parts of the quadrangle, back from the scarp. Indian Ridge, northeast of Hills-

ville, the Gibson Knob area near the eastern margin of the sheet, and parts of the Poplar Camp-Dry Pond-Macks Mountain range may be cited as illustrations. The projected profiles prepared by the writer show the accordancy of the hilltops and crestlines just described and furnish another evidence of the existence of an erosion surface in the Hillsville area at an elevation of 3000 to 3200 feet.

The Blowing Rock, North Carolina, Area

As one traces the Blue Ridge southwestward from the Hillsville region he finds an increase in elevation. On the eastern margin of the Wilkesboro quadrangle the Blue Ridge has an even crest at 3100 feet above sea level. It then rises rather rapidly to over 3500 feet, and even reaches 3900 feet in Little Grandfather Mountain, presumably a monadnock. Farther along, where the three forks of Reddies River, a tributary of the Yadkin, have gnawed deeply into the scarp its elevation is just above 3000 feet. In this last-named locality the present crest of the Blue Ridge is believed to be far below the Upland level, and represents the Harrisburg surface, as will be explained in a subsequent paragraph. As the scarp passes off the western margin of the Wilkesboro map to the Cranberry quadrangle (Plate XL) it has an elevation of approximately 4000 feet, which it maintains through the Blowing Rock region. Owing to the large number of monadnocks the peneplane here is less evident than in the Hillsville area. From Blowing Rock one gets an excellent view of Grandfather Mountain which seems to rise from its seat on the scarp, the crest of which is fairly accurately traced by the picturesque Yonahlossee road. When the traveler along this highway comes within several miles of Linville, he can see Grandmother Mountain, a monadnock to the east, rising apparently very definitely from the Upland level as shown in Plate XXXVIII. Finally from the summit of Grandmother Mountain (4686′) the view toward the south and west shows some very accordant crests. Jonas Ridge and Linville Mountain, two spurs of the Blue Ridge on the Morganton sheet which bound the valley of the Linville River below Linville Falls, seem to represent dissected

remnants of the upper level. In like manner the lower mountains in the extreme southwestern corner of the Cranberry map have reasonably accordant summits at 4000 feet.

The older peneplane was not developed in this area as perfectly as it was in the Hillsville region, because it lies near the headwaters of the master streams, and also because of the presence of extensive outcrops of rocks of superior resistance. Contrasts in rock resistance are much less marked in the Virginia locality.

The Area North and West of Asheville, North Carolina

The mountains which form the northern and western rims of the Asheville basin are thought to represent fairly well the present level of the Schooley Peneplane at elevations of 3100 feet and above. Although two sets of profiles of this area have been made, the writer does not feel justified in making a more definite statement of the present position of the upper level than to say that it probably stands at an elevation of approximately 3100 to 3200 feet above sea level in this region. A very instructive view of the Asheville basin and its rimming mountains may be had on a clear day from the top of Sunset Mountain, three miles north of Asheville. A grand sweep of mountains to the north, west, and south may be comprehended from this point. Pisgah Ridge surmounted by Big Pisgah Mountain (Plate XXXIX) to the southwest, and Newfound Mountain to the west, are impressive monadnock features which may be seen from this vantage point. A view which brings out a more perfect accordance of summit levels is had from points on the floor of the Asheville basin south of Asheville. One of these is shown in Plate XLI.

The Caesars Head, South Carolina, Area

So far as the present study has gone, the writer has found no other area south of Virginia in which the Schooley surface seems to be as well preserved as in the area drained by the eastern and southeastern tributaries of the French Broad River in North and South Carolina. The writer has chosen the Caesars Head

locality as the type because of Keith's (56) lucid descriptions, and his excellent photograph of the scarp from this point. He recognized the presence here of an extensive peneplane which is preserved along the crest of the Blue Ridge. Its elevation varies from 3000 to 3200 feet, with an average of about 3100 feet. In fact, many areas which the writer interprets as remnants of this surface are enclosed by the 3100 foot contour line.

Traces of this peneplane may be picked up at various points on the Saluda quadrangle, especially along the range which culminates in Tryon peak, north of the city of Tryon. The mountains along the meridian between the Saluda and Pisgah quadrangles, extending from Jumpoff Mountain, west of Hendersonville on the north to the scarp, ten miles to the south, preserve the peneplane. The triangular area bounded by this line on the east, the French Broad River on the northwest and the Blue Ridge on the southeast, constitutes the Caesars Head area proper. It extends as far as Lake Toxaway on the southwest. This territory embraces an area of at least one hundred square miles. In this district there are only a few well-defined monadnocks, such as Rich Mountain (3779′), Stone Mountain (3647′), and Pinnacle Mountain (3662′).

The peneplane is preserved only in interstream areas and mostly along sharp divides. The tributaries of the French Broad developed mature valleys in Harrisburg time, and remnants of these valley floors may be found above the floodplains of the present streams.

The evenness of the Upland surface is well shown from a number of different points. An eighty-foot tower has been erected about one mile southwest of Saluda, from the top of which the skyline to the southeast is fairly even as shown in Plate XLII. Excellent views in all directions may be had from Jumpoff Mountain. Unfortunately there are few days in summer when the atmosphere is clear enough to see long distances. To the east lies the Hendersonville portion of the Asheville lowland, beyond which rise the dissected remnants of the Schooley Peneplane. To the north is seen the Asheville basin proper, and to the west the high Pisgah Ridge, a monadnock above the Schooley

level. As the observer turns to the southwest he sees a great stretch of Schooley surface surmounted by several low monadnocks.

Keith's well-known photograph (56) showing the Piedmont surface on the east cutting into the base of the Blue Ridge scarp, the crest of which is continued westward as a rolling upland surface, brings out the essential elements in the type area at Caesars Head. The view looks toward the southwest. In Plate XLIII we see the Upland Peneplane and also Rich Mountain (3779′), one of the few monadnocks in this area.

Warping of the Schooley Peneplane

The present remnants of the peneplane in the four areas just described range in elevation from 3100 to 4000 feet. The approximate altitudes are as follows: Hillsville, Virginia, 3100 feet; Blowing Rock, North Carolina, 4000 feet; area north of Asheville, North Carolina, 3100 feet; and Caesars Head, South Carolina, 3100 feet.

In the explanation of the disparity in elevation of different parts of this erosion surface considerable emphasis has been given by Hayes and Campbell (34) to differential uplift or warping. While it is true that this peneplane was appreciably warped during uplift it is also possible that there was a considerable downstream slope on the original surface. It is interesting to note that the slope from Blowing Rock toward the north is exactly the same in direction as the slope of the Harrisburg surface developed by the New River. The descent toward the southwest is likewise in accord with the slopes of Harrisburg levels which extend toward Asheville.

THE HARRISBURG (VALLEY) CYCLE

General Statement

When the Schooley Peneplane was uplifted, a new period of erosion was inaugurated which continued long enough to produce a peneplane in areas underlain by soft rock, such as limestone and shale. The long, narrow Appalachian Valley, extending from New York to Alabama has been the classical area for the lower peneplane. It has been called Tertiary, because it was believed to have been developed in Tertiary time, and Harrisburg, because of its recognition in the Valley portion of Pennsylvania near Harrisburg, and "Valley" because of its occurrence in soft rock lowlands. It is more or less perfectly preserved in all parts of the Valley to the west of the Older Appalachians of the South.

Willis (77) refers to the floor of the Appalachian Valley as representing an approach to base level. It was regarded by this author as the latest of the erosion surfaces of the region and younger than the Asheville peneplane. In a paper by the present writer an attempt was made to correlate the Appalachian Valley peneplane with the Asheville peneplane, and other erosion levels in the Older Appalachians, and to show that all were produced in the same cycle of erosion. It is now believed that we can go still further in the matter of correlating the various levels in the Older Appalachians with those of the Appalachian Valley and the Allegheny Plateau on the west, and also with the Piedmont on the east and south.

Extent and Nature of Harrisburg Erosion

Since there are no extensive belts of weak rock in the Older Appalachians adjacent to the Appalachian Valley, there are no large Harrisburg areas in this province which connect directly with the Valley. Furthermore, since the western portion of the Older Appalachians is to a large extent made up of quartzite and other resistant rocks across which the streams must flow, the erosional features produced in the Harrisburg cycle in this area stand appreciably above the Great Valley. The evidences of Harrisburg erosion in the mountains, on the present interpretation,

are very abundant. Even in the areas where the Schooley is well preserved the streams in Harrisburg time left their record in mature valleys which can still be seen. The great monadnock areas rising above the Schooley, areas which have probably never been reduced so far as we can tell, are the places where few traces of Harrisburg dissection can be found. This, of course, is to be expected. It should be emphasized that in the areas where the Upland Peneplane is well preserved, stream dissection has destroyed all of the erosion surface in most cases except on the rather narrow divides. Because of accordance in level of the Schooley remnants in such areas it is probable that they have not been greatly reduced by erosion, and still represent essentially the original surface of the peneplane.

In all cases where the streams in Harrisburg time were able to develop local peneplanes it is believed that the rocks underlying such areas were of relatively low resistance. This peneplane is restricted to soft rocks in other parts of the Appalachians and the same holds true in the Older Appalachians of the South. It is quite true, of course, that the larger areas of Harrisburg surface are usually found along the larger streams, but there are splendid examples of this level developed by small streams at high elevations, whereas at many other places large streams barely reached maturity. Furthermore, the local peneplanes are open basins developed by a stream and its tributaries in the upper part of its course, while lower down the master stream was only graded. These areas are, therefore, commonly surrounded by mountains and the outlet stream has cut a narrow gorge in the floor of its former mature valley. This is particularly well illustrated by the Asheville basin drained by the French Broad River. The level of the Valley Peneplane at Newport, Tennessee, where the French Broad enters the Valley, is about 1200 feet. Traces of the former mature valley floor of this stream are found on the entrenched meander spurs rising upstream from the Valley at Newport to Marshall, North Carolina, where the mature valley ends and the remarkably fine local peneplane begins.[4]

[4] In this essay the term "local peneplane" is used to denote a peneplane of small extent but large enough to include interstream areas. In other words it involves an area drained by a master stream and at least a few tributaries.

Davis (27) applies the term "local peneplain" to the Asheville Basin, thus: "here the normal cycle of erosion has gone so far that valley floors have been opened to form local peneplains, five, ten, or twenty miles across: the best known of these being that of the French Broad River. . . . ."

In further support of the statement that the Harrisburg is a soft-rock peneplane, it may be noted that relatively weak minerals occur abundantly in these areas. Throughout many miles of traverse across these basins the writer was often impressed by the high percentage of feldspar in the rocks. Feldspathic types seem to predominate where the Harrisburg is developed in crystalline rocks. There are considerable variations in the relative proportions of different minerals in rocks that are mapped as the same formation. In places the cleavable dark minerals, such as hornblende and biotite, occur in relatively large quantities. Rocks that are high in quartz are apt to rise above the peneplane.

Monadnocks on the Harrisburg (Valley) Peneplane

Strictly speaking the remnants of the Schooley Peneplane and the monadnocks above it are areas that were not reduced in Harrisburg time and hence are monadnocks above this peneplane. For the sake of clarity, however, we shall speak here only of those features which rise appreciably above the Valley Peneplane but which do not reach the Schooley level.

As elsewhere, the Harrisburg monadnocks are ordinarily neither imposing nor numerous. They are scattered around the margin of the Asheville basin, especially south of Hendersonville, and rise several hundred feet above the peneplane level. An excellent example is seen northwest of Skyland in the northwestern corner of the Pisgah quadrangle. It bears no name but may be recognized on the map by two tiny areas enclosed by the 2700 foot contour line. In the field it appears as a sharply defined feature west of the Asheville-Hendersonville highway. Another, also unnamed, is located about three miles southwest of the one just described and about two miles west of Arden.

Similar features are found also in the basins of the Linville, North Toe, South Toe, Hiwassee and Toccoa Rivers. Some are

conical hills, others are low ridges. Many bear no names on the map and they are usually not conspicuous. In some places, especially around the margin of a basin, they may become numerous enough to make difficult the recognition of the peneplane level. In the Hiwassee basin as the monadnocks become numerous near the margin, the local peneplane gives way to mature valleys which continue among the monadnocks.

Summary of Harrisburg Erosion

In spite of the fact that this cycle was much shorter than the Schooley, there are many features in the present topography that were formed or reshaped in this cycle. In the great monadnock areas like the Great Smoky and Black Mountains, which withstood Schooley erosion without being baseleveled, the rocks were so resistant that no appreciable progress toward peneplanation was made in the Valley cycle. In such localities the writer has thus far been unable to discriminate between the work of the different cycles.

In the areas which still preserve the Schooley level, we have seen that Harrisburg erosion removed almost everything except the divides, and while the accordance of hilltops is still the most important element in the topography, the amount of dissection accomplished in the second cycle is indicated by the extensive development of mature valleys and the sharpening of the divides.

Finally, a considerable number of local peneplanes and mature valleys are definitely assignable to the Valley cycle. Following the consideration of the Asheville Basin we will start with the southern tip of the Older Appalachians and proceed northward.

Harrisburg Local Peneplanes

The French Broad Basin

The largest and most perfectly developed local peneplane in the Older Appalachians was formed by the French Broad River and its tributaries. It is beautifully preserved around Asheville, the city itself being built in part on the remnants of this surface, and in part on the slopes leading down to the river. Willis (77)

first described this region in explanatory terms. He recognized the fact that this surface was produced during a long cycle of stream erosion. This writer regarded the Asheville as an older peneplane and the floor of the Appalachian Valley as a younger surface. Older than both of these was the level preserved on the high Unakas. He described the Asheville "amphitheatre" in very discriminating words, as follows:

"Riding away toward the sunset, I traversed the old plain without seeing that it had had a continuous surface. I noted the many gullies, and I lost in the multitude of details the wide level from which they were carved. That the broader fact should be obscured by the many lesser ones is no rare experience, and perhaps there is no class of observations of which this has been more generally true than of those involved in landscape study. But when once the Asheville plain has been recognized, it can never again be ignored. It enters into every view, both as an element of beauty and as evidence of change in the conditions which determine topographic forms. Seldom in the mountains can one get that distance of wooded level, rarely is the foreground so like a gem proportioned to its setting; all about Asheville one meets with glimpses of river and valley, sunken in reach beyond reach of woodland which stretch away to the blue mountains. The even ridges form natural roadsites, and in driving one comes ever and anon upon a fresh view down upon the stream far across the plain and up to the heights."

The basin extends along the French Broad River from Marshall on the north up to Brevard on the south, a distance of forty-five miles. From Brevard on to Rosman its presence is detected in small remnants and the writer believes it extends as far as Lake Toxaway on the southwest. It has a maximum width in the Asheville area of fourteen miles.

The basin is seen in all directions from Hendersonville. This territory is in the drainage basin of Mud Creek, a tributary of the French Broad. When viewed from Jumpoff Mountain west of Hendersonville, the country to the east is so well planed off that it resembles the Piedmont. A similar view looking southwest may be had from Sugarloaf Mountain in the north central portion of the Saluda quadrangle, Plate XXXVI.

A narrow arm of the same basin extends up Swannanoa River from its junction with the French Broad at Asheville to Black Mountain. Above the village of Swannanoa it is more nearly a mature former valley than a local peneplane. Another upstream extension occurs along Cane Creek. An especially open basin drained by this stream, centers around Fairview in the southwestern corner of the Mt. Mitchell quadrangle. The elevation here is over 2500 feet.

There are few monadnocks on the Asheville surface and it is essentially a high-lying basin rimmed by mountains. Especially good views of the Asheville penepane may be had from Sunset Mountain and Gooch Peak north of Asheville. It is also very impressive as one drives along the highway leading down to Marshall, or along the road to Canton, and especially as seen from the road leading to Saluda by way of Hendersonville.

The elevation of the peneplane is approximately 2400 feet at Rosman on the French Broad, 2300 feet along the divides east of Hendersonville, 2400 feet in the Swannanoa Valley around Black Mountain, and 2350 feet on Hominy Creek near the Haywood-Buncombe County line. At the downstream end of this basin where the French Broad enters its gorge, the elevation is about 2100 feet. There is thus an appreciable downstream slope along the four main drainage lines which converge to form the French Broad River.

Stream gravels which seem to show about the same degree of weathering are found scattered over the rolling hills whose strikingly accordant summits preserve the level of the peneplane. They were studied at many different localities but especially on the hills in and around Asheville.

The extent of dissection varies from a maximum of more than two hundred feet near the lower end to less than one hundred feet in the upper part of the Hendersonville locality. Near Black Mountain the Swannanoa River has not been able to sink its channel more than fifty feet below the position it had in Harrisburg time. An interesting contrast is brought out by a comparison of the grades in the streets of Asheville with those in Brevard where the depths of dissection is less than half as great as in Asheville.

While all of the streams which drain the upland west of the Blue Ridge scarp have lost territory to the more aggressive eastern streams, the French Broad River has been an especially heavy loser. There is an area around Saluda, North Carolina, about ten miles southeast of Hendersonville, which is drained by the Green and North Pacolet Rivers. These streams have cut off a strip of the former French Broad basin about ten miles wide and at least twelve miles long, and have dissected it to a depth of hundreds of feet. The summits of the interstream areas are remarkably accordant, as seen from a tower near Saluda, and obviously represent an eastward extension of the very slightly dissected peneplane of the Hendersonville area. In the latter case the country has many open fields while in the Saluda area forest covers practically the entire surface, including the steep slopes and the narrow strips of upland that remain. Open valleys characterize the French Broad basin while narrow ravines and gorges are typical of the basins of the pirate streams.

The same sort of thing has happened all along the scarp from Saluda to Lake Toxaway, and even to the basin of the Horsepasture River. It is more than likely that this stream flowed originally into the French Broad. It has a rather large drainage area at present and formerly it had an even larger one, for it too has lost to pirate streams. The loss of the Horsepasture was serious so far as the French Broad was concerned because it carried a large part of the headwater drainage. The misfit meanders of the French Broad River several miles south of Brevard may be due, at least in part, to this event.

The Ocoee Basin

Toccoa River has its source in tributaries which drain the northern slope of the Blue Ridge in the highland of northern Georgia and flows northwestward by Copperhill, a mining city located just across the state line in Tennessee. Below this point the Toccoa is known as the Ocoee until it joins the Hiwassee River in the Appalachian Valley. The best development of the Harrisburg Peneplane is along that portion of the stream which bears the name Toccoa, but since the entire basin ties up with the

Valley Province downstream, the writer has used the name of the larger and better known river.

The area under consideration includes a large part of Fannin County, Georgia, represented on the Ellijay, Georgia-North Carolina-Tennessee topographic map; a triangular area centering around Ducktown, Tennessee, in the southwestern corner of the Murphy, Tennessee-North Carolina, map; and a strip extending along the valley of the Ocoee River to its junction with the Hiwassee on the Cleveland, Tennessee quadrangle.

Keith (60) has compared the shape of this basin which he calls the Ducktown Plateau, to "an oak leaf, the various tips lying upstream on the tributaries of the Toccoa River, and the stem of the leaf being downstream in Tennessee."

In a northwest-southeast direction the well-developed Harrisburg surface can be traced for at least twenty miles, and it continues much farther in the form of mature valleys. Its greatest width is perhaps twelve miles. Throughout this territory the accordancy of hilltop, which is very striking, and quite similar to the Asheville area, is broken by relatively few local monadnocks. At no place do they become numerous or massive and the basin is not notably constricted by them. In view of the areal extent of this surface and the further fact that the basin is drained not only by the master stream but also by dozens of tributaries, it is thought that it should properly be called a local peneplane. The divides between tributaries are, in many places, very accordant in elevation.

Excellent views of this basin may be had from the highway across Little Frog Mountain north of Ducktown, Tennessee, and from various points along the road between Ducktown and Blue Ridge, Georgia. A typical photograph of this basin is reproduced in Plate XLIV.

A fact of interest in this basin is the depth of rock decay. The writer has frequently observed in different basins of the Older Appalachians the rather rare occurrence of bold rock outcrops and, on the other hand, the relatively great depth of the soil. Keith (60) has said that the "rocks are decomposed on the older upper surfaces of the [Ducktown] Plateau, to depths

from five to sixty feet, ... " An impression of the depth of the soil and the gullying produced by tiny streams where the vegetation has been removed by poisonous fumes may be gained by examining Plate XLV.

Another feature which is characteristic alike of this and many of the other basins is the intrenched meandering course of the master stream as it flows through its basin. These meanders may be found as far upstream as the peneplane can be traced, and they occur below the point where the stream enters its gorge and the local peneplane disappears. Especially good examples of incised meanders may be seen around Wilscot, also northeast of the town of Blue Ridge, and above and below Copperhill. Bends that are interpreted as meanders, but which are less typical than those cited above, occur throughout the narrow course of the stream as it passes through the resistant rock belt below Copperhill. It is quite possible that the main tributaries may show incised characteristics farther upstream than the peneplane extends, where only a mature valley was developed in Harrisburg time. This rather impressive chain of second cycle meanders seems to indicate a unity in the history of the basin, for it is rather unlikely that meanders of such apparent similarity were developed along a single stream in two different cycles. One would naturally inquire concerning the record of erosion in the later cycle, in the case of those meanders which supposedly might date back to a cycle earlier than the Harrisburg. In the apparent absence of any such erosional record the writer is inclined to interpret this series of meanders as belonging to a single cycle.

Because the master stream, the Ocoee in the lower part and the Toccoa in the upper, has barely reached maturity in the present cycle, the cycle during which this basin was developed was the latest that has even approached completeness in this region. Since, as will be seen later, this level seems to tie up with the Appalachian Valley floor, the writer feels that there is evidence of a unified erosional record in the extreme southern portion of the Older Appalachians.

The elevation of the Harrisburg surface at the lower end of the district where it is well preserved, a few miles northwest of

Copperhill, is approximately 1600 feet. It averages 1700 feet around Ducktown, and also on the hills on both sides of the Toccoa River in the vicinity of Copperhill. As one approaches the mountains which form the lateral boundaries of the Harrisburg lowland, the accordant hills attain a height of 1800 feet. Proceeding upstream, the peneplane level gradually rises until in the Wilscot locality it is 2100 feet above the sea. It is perhaps unsafe to attempt to carry the peneplane level much farther, but it is quite probable that traces of the former mature Toccoa valley may be found at increasingly higher elevations upstream.

The lower part of the open Harrisburg basin is about sixteen miles, as the stream flows, from the Appalachian Valley. The level of the Valley Peneplane is about 900 feet above the sea, and 700 feet below the local peneplane of the Ocoee River. These two areas are connected by an intrenched meandering stream. It does not seem unreasonable to suppose that a stream will develop a meander belt with a gradient of forty-five feet per mile. Turning in the opposite direction the increase in elevation in approximately twenty-six miles is five hundred feet or twenty feet per mile. This occurs in the soft rock area which was peneplaned in Harrisburg time.

In the light of the above evidence the writer interprets this basin as a local peneplane developed in relatively weak rocks by a master stream, which flowed across a downstream hard rock area where it was able to develop only a mature valley with a narrow meander belt. The downstream slope of the peneplane surface from 2100 to 1600 feet is believed to be, for the most part, original rather than due to warping.

The streams in the present cycle have intrenched themselves into the surface which they carved in Harrisburg time. Near their heads they flow almost at the same level at which they flowed in the former cycle, and their valleys are broadly open. Going downstream they sink deeper and deeper in their modern trenches until they are 300 or more feet below the peneplane level. Back from the streams the divides are broad and the topography is relatively smooth.

An interpretation which differs from the one just given has

been set forth by Keith (60). "The surface of the Ducktown Plateau is everywhere rounded and its summits are between 1600 and 1800 feet above sea." Also, "Where the mountains are well-developed there is no uncertainty about the boundary of the Plateau, for the slope of the ground changes there rather abruptly. In the southeast and southwest parts of the Plateau, however, there are many remnants of an older and higher plateau than the Ducktown, which stand above 2000 feet in height. Between the two plateaus the boundary is less plain and must be drawn largely by means of their altitudes, since their forms are alike. The difference in heights is usually between 200 and 400 feet and higher plateau remnants are excluded from the Ducktown Plateau, because they are connected with and belong to the Hiwassee Plateau."

It will be noted that the above author distinguishes between the Ducktown and the Hiwassee Plateaus on the basis of elevation. The upper part of the Ocoee basin, where the erosion surface is over 2000 feet in height, is classed with the Hiwassee basin. Keith apparently means to assign the higher level an earlier date as he did in a former paper (48). The present writer believes that the surfaces in the different basins are not correlatable on the basis of elevation because of the variable factors of stream volume, stream length, rock resistance, and the nature of the downstream rocky barrier. All of the independent basins, however, are alike in the uniform upstream rise of the peneplane, and also in their apparent genetic connection with the peneplane of the Appalachian Valley.

The Hiwassee Basin

The Hiwassee River has a much larger drainage basin than the Ocoee to the south and carries off the surface discharge from a district including parts of Georgia, North Carolina, and Tennessee. Its head is against the slopes of the Blue Ridge in Towns County, Georgia, and it enters the Tennessee River twenty-five miles northeast of Chattanooga, Tennessee. The area to be described is represented on the following five topographic maps of the United States Geological Survey: Dahlonega, Georgia-

North Carolina; Ellijay, Georgia-North Carolina-Tennessee; Nantahala, North Carolina-Tennessee; Murphy, Tennessee-North Carolina; and Cleveland, Tennessee.

The Ocoee, which joins its master in the Appalachian Valley, may be considered an independent basin, so far as the Older Appalachians are concerned. The name Hiwassee is borne by the main trunk stream to a point above the village of Hiwassee. A dozen creeks flowing from the south, east, and west unite to form the Hiwassee in this vicinity. In addition to many small tributaries the Hiwassee is joined near Murphy, North Carolina, by two important rivers. Valley River, with its head twenty-five miles to the northeast near Red Marble Gap, flows through a basin between the Snowbird Mountains on the north and the Valley River Mountains on the south, and enters the Hiwassee at Murphy. Nottely River, coming from the southwest and entering the Hiwassee several miles below Murphy, flows through an open basin whose boundaries are not sharply defined by steep mountain slopes.

The alignment of Valley River and the lower course of Nottely River, as well as other streams to the southwest, such as Papermill, Young Stone, and Cherrylog Creeks, is one of the striking drainage features of the region. Keith has called attention to the occurrence of the Murphy marble in this area and has used it as an illustration of a weak rock. In the Ellijay Folio he discusses the Murphy fault and gives its length as approximately one hundred miles. This faulted marble belt is truly a valley-maker, and it has been the controlling influence in the location of this chain of northeast-southwest trending valleys. This arrangement is all the more striking in view of the prevalent dendritic stream pattern in this region.

The local peneplane, as the writer interprets it, can be traced along the Hiwassee from the point where the stream enters the resistant barrier, as shown on the Murphy map, up to and slightly beyond the village of Hiwassee. Below Hayesville on the Nantahala quadrangle, the basin narrows down and is closely bordered by mountains. In this locality the stream in Harrisburg time produced only a mature valley while upstream, beyond

Hayesville, there is a strip of country extending south into Georgia, whose interstream areas are very accordant. Here the term local peneplane may properly be applied.

The Nottely basin as far as Blairsville and beyond, a distance of twenty miles from its junction with the Hiwassee, shows a magnificent development of the Harrisburg level. The writer has not visited the Valley River basin, but from the map alone the presence of the erosion surface there is apparent. The floor of this valley between Marble and Andrews is wide and flat, and few traces of the Harrisburg level appear near the stream. This is doubtless due to the very low resistance of the marble underlying the valley which has permitted the stream in the present cycle to attain a more advanced stage than most streams in the crystallines. Contrast the broad mature valley of this tributary stream with the narrow gorge of the master stream thirty-five miles downstream where it is cutting through resistant rocks. The effects of variations in rock resistance in this area are very impressive.

The Harrisburg level seems to be pretty well preserved along the sides of the Valley River basin at an elevation of 1800 to 1900 feet, in the lower part of the valley, while above Andrews it reaches an altitude of 2000 to 2100 feet. It must be remembered that the elevation increases as one goes toward the sides of these basins as well as upstream. It is quite possible that remnants could be found close by the river as low as 1700 feet near the junction with the Hiwassee. A very interesting apparent corroboration of this idea is suggested by "The Glades," an almost flat area about four square miles in extent resting against the southern slope of the Snowbird Mountains. A rather pronounced scarp, extending from the 1800 foot contour up to the 2000 foot contour, separates this elevated little basin from the broad valley floor of the main stream. Its elevation, 2000 to 2100 feet, is just what it should be if interpreted as part of a former, much more extensive erosion surface, the main central portion of which has been eroded away by Valley River in the present cycle.

The notably barbed character of some of the tributaries of

Valley River which enter from the north is a bit puzzling. Hyatt Creek, flowing in near Marble is a case in point. Better examples are Holland and Patterson Creeks near Andrews. There are others, such as Vengeance Creek, which are slightly barbed, but the majority of the tributaries join the master stream at angles that are normal for the dendritic pattern. The map evidence is hardly sufficient to justify an explanation on the basis of reversal in direction of flow. The influence of the distribution of hard and soft rock belts might be worth investigating.

The soils of the Nottely basin especially were observed to contain large quantities of kaolin. This indicates, of course, a high feldspar content in the original rocks. Rocks carrying high percentages of feldspar and other weak minerals are common in these basins.

The intrenched meanders of this basin are beautifully developed, and the intermeander spurs which preserve the ancient floodplain, rise upstream in accordance with the increase in height of the more extensive peneplane remnants back from the master stream. These meanders occur both in the hard rock area on the western side of the Older Appalachians, as well as in the softer rock areas upstream where the peneplane is well-developed. Nottely River also has cut down in its old meander belt. On the other hand, Valley River has only a few remnants of intermeander spurs. This is doubtless due to the fact that the stream has been able to erase these features in an area of rock so weak that a broad floodplain has been developed in the present cycle.

The suggestion of the present writer is that this long chain of intrenched meanders on the Hiwassee and Nottely Rivers indicates a unity in the erosional history of the region, and points to the last complete cycle as the time in which they were formed. It is doubtful whether meanders are likely to be preserved throughout a subsequent cycle and well into a still later cycle with so few evidences of the ravages of erosion as these possess, except in areas of extremely resistant rock. The upstream meanders in weak or moderately weak rocks seem to offer no serious problem, but the writer still retains a mental reservation

in regard to those in the rocky barrier downstream. Softer rocks do occur in this area of high average resistance, and it is possible that the meanders may have been developed chiefly on such rocks. Furthermore, even if the meanders of the hard rock area were developed on a Schooley floodplain, this would not destroy the validity of the main thesis here presented so long as there are traces of a mature valley along the course of the stream through the hard rock belt.

The peneplane stands at an elevation of 1500 to 1600 feet where the Hiwassee River breaks through the Unaka-Little Frog range and rises upstream to 2100 feet near the village of Hiwassee. The altitude is approximately the same in the upper portion of the Nottely and Valley River basins. The traces of the mature valley, below the point where the local peneplane is well-developed, descend in height rather rapidly from 1500 or 1600 to 900 feet, which is approximately the level of the Valley floor where the Hiwassee enters the Appalachian Valley. Just behind the westernmost barrier there is a broad local area of moderately weak rocks which was apparently peneplaned in Harrisburg time.

A comparison of the difference between the gradient of the present stream and the downstream slope of the peneplane brings out an interesting and puzzling point. Let us think of the two parts of the basin which have been described as the upper, open section where the local peneplane is developed on rocks of moderate to low resistance, and a lower section of chiefly hard rocks with some weak belts, where the stream in the Harrisburg cycle developed only a mature valley. At some places in the hard rock belt the stream was doubtless just graded, while at others, where the rocks were weaker, it made a broader floodplain with a wider meander belt. In exceptional cases the tributary streams were able to bring their valleys to grade and reduce the interstream areas to low divides. Here there are found today traces of the local peneplane developed more extensively upstream. The length of the upper section in the Hiwassee basin is approximately fifty miles, and the lower section fifteen.

The elevation figures used below are taken from the topographic maps where the contour interval is 100 feet. Further-

more, the author believes that a margin of error of one hundred feet is not too much to allow in estimating the altitude of most peneplane remnants, especially without the aid of numerous profiles. Hence the following figures can be only roughly accurate.

The present stream elevations are about as follows: 1950 feet, at upper limit of peneplane development, 1200 feet where it enters the gorge at lower limit of well-developed peneplane, and 700 feet where it enters the Valley. The peneplane has the following altitudes at the same points, 2100, 1500, and 900 feet respectively. The drop of the present stream is 1250 feet, while the peneplane descends 1200 feet in the same distance. At the two ends of the upper section the difference in stream elevations is 750 feet and the difference in peneplane level is 600 feet. This seems quite normal for the stream has cut deeper into the basin floor in the lower part than in the upper. In fact, as we go beyond the uppermost limit of the peneplane, we find the stream almost if not entirely at the level at which it flowed in the former cycle.

When we examine the lower section, we find the difference in present stream levels to be 500 feet while the traces of the mature valley descend in that distance 600 feet. It seems improbable that the present stream should have a gentler slope than the former valley. It must be remembered, of course, that these figures are only roughly correct. Nevertheless, this apparent disparity must be considered. Those who pin great faith on present altitudes in the correlation of erosion surfaces will not be inclined to credit the present interpretation in which erosion levels of highly varying present elevations are believed to be genetically related and hence assigned to the same cycle.

We are dealing in this area with three sharply contrasted rock belts. There is an area of hard rocks, with a few weaker members, in the middle course of the Hiwassee which we have just been considering. Above this zone, to the east, there is a district on rocks of intermediate resistance, but including a few very hard members. To the west of these two belts is the Great Valley, underlain by weak limestone and shale, with subordinate cherty members.

It is obvious that all parts of the Harrisburg surface have been reduced by erosion in the present cycle. The present writer believes that the Valley Peneplane has been lowered more rapidly than the corresponding levels in the crystallines for the following reasons. The limestone and shale are much weaker than the crystallines, and especially the lower belt of crystallines. In the next place the limestones weather by solution, which permits the rather rapid reduction of interstream areas. Finally, this area is near the great master streams where the effective work of the present cycle has been going on much longer than in the crystallines. The fact that the limestone area has been greatly reduced in post-Harrisburg time is amply attested by Hayes (42), who even admitted the formation of a lower peneplane, known as Coosa, in this time. It is probably not extravagant to suggest that the Harrisburg level in the Valley has been reduced hundreds of feet since its completion. This factor alone may be responsible for the apparently too steep slope of Harrisburg remnants.

In addition to the above, it might be pointed out that the present gradient of the lower Hiwassee may be almost as gentle as it was at the close of the Harrisburg cycle. At some places it even has a floodplain, as may be seen in Plate XLVI. The lowering of the gradient is largely accomplished in the early part of the cycle in the downstream portions of streams.

It might be noted, also, that the comparison is between stream gradient and peneplane slope which, in the present state of our knowledge, has no great value. In these basins it has been observed that the volume of the water and especially the resistance of the rocks are important factors in determining the slope of the local peneplane surface. They all descend downstream without regard to the direction of flow. Exceptions are found only where piracy has occurred.

The reader can perhaps gain a clearer conception of the nature of the drainage basin of the Hiwassee by examining several photographs taken by the writer on a trip up the valley. We first pass through the narrow valley in the area of hard rocks where the valley sides are steep, rocky walls. The next view we

get is about one and a half miles above the gorge, and shows a narrow floodplain with Harrisburg hills beyond (Plate XLVI). This is still in the general area of resistant rocks, but locally the rocks are weak, and a strip of Harrisburg surface was developed. The highway now leaves the valley and climbs Little Frog Mountain, from the eastern side of which we get an excellent view of the Harrisburg country just mentioned, as well as the gap in the resistant Beans Mountain-Starr Mountain ridge. This view is reproduced in Plate XLVII. The high level valley, below which the notch occupied by the present stream is cut, is quite striking. Immediately one wonders which level here represents the Schooley. The writer is not prepared to answer. It is his impression, however, that this high-lying valley represents the floodplain of the Hiwassee River in Schooley time and that the higher ridges on each side of the gap were low residuals on the Schooley surface. On the right side of the picture it will be seen that the ridge crest of Starr Mountain has about the same elevation as the floor of the Schooley (?) valley. The same is true in the case of a part of Beans Mountain, as it extends to the left beyond the border of the photograph. There seem to be traces of the Schooley level at other places in this area at elevations of 2000 to 2200 feet.

The next illustration (Plate XLVIII) was taken from the highway on the divide between the Ocoee and Hiwassee basins about five miles north of Ducktown, Tennessee. The area in the range of the camera lies on the Murphy quadrangle, the mountains in the background being the southern end of the Unakas. In this view we see the well-developed Harrisburg Peneplane in a direction transverse to the course of the Hiwassee River. Its width here is about a dozen miles and it is without a single prominent monadnock. It appears that we can see in this photo the gentle downstream (right to left) slope of the peneplane surface, but this may be an optical illusion. In the last picture (Plate XLIX), we see the basin as it appears near Hiwassee, almost the upper limit of the peneplane. The low, accordant wooded hills with the central lighter area are a hundred feet or more above the present floodplain. This strip of lowland, a mile or so wide, is bounded here by steep mountain slopes.

The writer believes that the Hiwassee basin exemplifies the work of erosion in the Harrisburg cycle. It is thought that the moderately dissected upstream local peneplane developed on crystallines of intermediate resistance may be correlated, through the remnants of a mature valley in the hard crystallines, with the once extensive Harrisburg Peneplane in the Appalachian Valley, which, at the time of its completion, stood perhaps several hundred feet higher in relation to the upper local peneplane than it does at the present time. It is natural to suppose that the Schooley Peneplane was developed in the same area even more extensively. It has already been pointed out tnat there seem to be traces of this surface at elevations of 2000 to 2200 feet, and back nearer the divides it may rise several hundred feet higher. The heads of some of the streams which now flow at approximately their Harrisburg levels are only a few hundred feet at most below the Schooley level. The Harrisburg surfaces descend rather rapidly downstream while the Schooley remnants slope less steeply. The Schooley level is rather difficult to trace in the southern tip of the Older Appalachians because of the widely varying resistance of the rocks. In very hard rocks, the monadnocks are numerous while in the weak rocks the surface was reduced to the Harrisburg level.

For a very complete description of this and other basins lying in Georgia, the reader is referred to the work of Keith (60) in "The Physical Geography of Georgia." In regard to the origin and nature of the topographic features this author has the following to say: "The Hiwassee Plateau is usually from 400 to 500 feet higher than the Ducktown Plateau, and parts of the upper plateau are found around the margins of the Ducktown Plateau. Except for the differences in altitude the individual features of the Hiwassee Plateau are about the same as those of the Ducktown. This is natural because each plateau represents the work done by the same factors (the streams and processes of decomposition) upon the same sets of rocks. Individual formations reach directly across from one plateau to the other and also from one part of the Hiwassee Plateau into other parts. . . . . The limits of this Plateau are set where the gentle plateau top rises

rather sharply into the mountain slopes, usually around 2,100 feet. The outline of each section of the Plateau is very crooked, and each has the leaflike form shown in the Ducktown Plateau. . . . . The Plateau extends up Nottely River until it is only two miles from the Blue Ridge and the reduction to the Plateau grade throughout its length was remarkably complete. It is more so than on the upper Hiwassee, which is the main stream where the Plateau is decidedly narrow as is seen in Plate XXXI-A. . . . . As the Plateau becomes more and more dissected toward the north, the roads and settlements tend to keep to the smooth upland portions. This is most plain in the lower part of the Nottely basin, where the trenching produced minor valleys in the Plateau at the Ducktown Plateau level, which were in turn still farther trenched below that level. . . . . The stream grades in the Hiwassee Plateau are fairly steep but do not compare in this particular with those south of the Blue Ridge. The margins of the Plateau next to the mountains are about 2,100 feet above sea, and outside of them the streams rapidly increase in grade. Within the Plateau, however, they promptly flatten out to grades which are moderate."

In the above extracts, as elsewhere in the volume from which they are taken, the author uses elevation as the primary basis for the distinction between levels. A little different tone is detected in that part of the quotation where he says, "The Plateau extends up the Nottely River until it is only two miles from the Blue Ridge and the reduction to the Plateau grade throughout its length was remarkably complete." This "Plateau grade" extends down to the junction of Nottely and Hiwassee Rivers, and continues on down the latter to the point where the valley becomes constricted. When this larger area is considered it will be seen that even on the basis of altitude there is no appreciable difference between the Ocoee and Hiwassee basins. The present writer contends that the elevation of these high-lying local peneplanes has no interpretative significance if they can be shown to tie up genetically with a more general peneplane downstream.

The Little Tennessee Basin

The next large stream north of the Hiwassee is the Little Tennessee River. Before taking up this basin, however, the writer wishes to call brief attention to Tellico River which rises on the western slope of the Unakas, between the Hiwassee and the Little Tennessee, and flows into the latter in the southern part of the Loudon, Tennessee, quadrangle. The Harrisburg surface is extensively developed in this basin, especially around Tellico Plains as well as in the region to the northwest called "The Red Knobs," a part of which is drained by Conasauga Creek, a tributary of the Hiwassee. This development of the Harrisburg correlates very definitely with the Harrisburg Peneplane in the Great Valley. In the Tellico Plains it has about the same altitude as the Valley Peneplane, but it rises 100 to 200 feet higher in "The Red Knobs." It seems obvious from the mainly subsequent position of the stream and the flat character of the present valley that the soft rocks of the Plains are connected by a weak rock belt with the limestones of the Appalachian Valley.

The headwaters of Little Tennessee River are near Keener and Rabun Gaps in Rabun County, Georgia, about six miles south of the North Carolina line. It flows northward and then northwestward to unite with Tennessee River near Loudon in the Appalachian Valley. Besides many small tributaries and Tellico River, there are three large tributaries, Cheoah and Nantahala Rivers coming from the south and Tuckasegee River from the east. The junctions of the last two streams with the Little Tennessee are only four miles apart in the northeast corner of the Nantahala quadrangle. The Cheoah unites with the Little Tennessee on the western side of the same map. The basin here described is represented mostly on the Walhalla, Georgia-South Carolina-North Carolina, Cowee, North Carolina-Tennessee, and Loudon, Tennessee topographic maps of the United States Geological Survey.

We will examine first the three large tributaries and then the master stream itself. Nantahala River occupies a narrow basin trending north and south in the eastern half of the Nantahala

quadrangle. It is bounded on the east by the Nantahala Mountains and on the west by a number of mountains including the Blue Ridge, Tusquitee, Valley River and Snowbird. It makes a sharp bend between Red Marble Gap and Nantahala due to piracy effected by a stream located on the northeastward extension of the faulted Murphy Marble belt previously mentioned. Keith (55) has described this drainage change in the following terms: "Originally the Nantahala flowed in a direct course down the Cheoah Valley. It was diverted about midway in its course by a branch of Little Tennessee River, working back along the soluble Murphy marble. Its old elevation of 2800 feet is marked by pebble deposits on summits $1\frac{1}{2}$ miles nearly west and 3 miles nearly southeast of Nantahala. On the upper reaches of both of these streams small plateaus and terraces, rarely over a mile in width, accompany the watercourses." The present writer has not examined in the field the evidence in support of capture but the map evidence is quite impressive. It includes: (1) a right angle bend in the course of the stream at the point where capture is supposed to have taken place, (2) the position of Tulula Creek, main stem of Cheoah River, which is the normal continuation of the Nantahala River below the "elbow of capture," (3) the broadly open character of the valley head of Tulula Creek, (4) the low altitude and flatness of the divide, (5) the absence of remnants of the Harrisburg erosion level with its associated intrenched meanders below the "elbow" on the present course of the Nantahala, and their presence above this point, as well as in the head of Cheoah Valley, (6) the steepened gradient of Nantahala River above the supposed capture.

If the above observations are correct, the date of the piracy is definitely fixed as later than the Harrisburg. At least it occurred after the completion of the erosion surface that is still well preserved in this region. The logical inference is that the rejuvenated tributary of the Little Tennessee, working on weak rocks tapped the waters of the Nantahala early in the present cycle.

The traces of the Harrisburg erosion level around the junction of the Cheoah and Little Tennessee Rivers, near the North Carolina-Tennessee line, are around 1600 feet in altitude. In

the vicinity of Robbinsville, some fifteen miles upstream where there are numerous remnants, it is about 2200 feet above the sea. As we follow it upstream from this point, we find only local remnants of a former mature valley because the stream is flowing through a belt of hard rock. It is in this area that the diversion of Nantahala River toward the northeast took place. The present elevation of the former valley at the divide between the Cheoah and Nantahala Rivers is about 2800 feet above sea level. Keith refers to the occurrence of stream gravels at this level. Continuing up the present valley of the Nantahala River, the former valley can be traced to Aquone, where it is above 3000 feet. Between Aquone and Slagle the stream flows in a deeply intrenched, winding, or meandering course, where the spurs apparently rise 500 feet above the present stream. These spurs are not characterized by flatness of surface, but they are reasonably accordant in the middle part of the stretch at a height of 3500 feet. In view of the fact that there is no clearly marked map evidence of Harrisburg erosion above this locality, the writer is uncertain as to the interpretation of these apparent meanders. They may have been formed in a cycle earlier than those of the more open Harrisburg territory.

The Tuckasegee River drains a large area located in the northern and eastern portions of the Cowee quadrangle. The Cowee Mountains, in the middle of the map, separate this basin from that of the Little Tennessee River. The course of this river is characterized by several rather broad expanses of Harrisburg country. The largest of these centers around Bryson and Whittier in the northwestern corner of the Cowee map. Another is found near Dillsboro and extends upstream from this locality along the main stream as well as along the valley of Scott Creek, a tributary that enters the Tuckasegee at this point. Between these two areas this erosion surface constitutes only a narrow strip along the river. The intrenched meanders noted in other basins are developed in splendid fashion along the Tuckasegee River, especially above and below Dillsboro, as well as along the Little Tennessee (Plate L).

In this basin we find a number of high-lying mature valleys

some of which are quite open and involve in some instances small, flat interstream areas between minor tributaries. Below these mature valleys are found falls and steep-walled rocky gorges. Let us take, for an illustration, Shoal Creek, which flows into the West Fork of Tuckasegee River about five miles south of the village of Tuckasegee. The upper part of this valley is an open basin and the form is quite mature, as may be seen in Plate LI. Following downstream we find a series of rapids and falls where the water descends into the valley of the main stream. In these rapids and falls the stream drops 400 to 500 feet in a distance of a mile. The stream is here flowing over a very massive rock barrier, as is indicated not only by the falls, but also by the great exposures of smooth rock surfaces on the mountain sides close to the falls. The mature upper basin has an elevation of approximately 3700 feet, and it unites with and is a part of the open country around Glenville, a village situated on Hurricane Creek just above its junction with the West Fork of Tuckasegee River. The latter basin is about 3600 feet in height. On the West Fork itself, there exists a fall and below it a narrow gorge.

These two examples are typical of a large number of similar features between Asheville, North Carolina, and the southern end of the Older Appalachians in northern Georgia. Another illustration is found in the area called "The Flats," located near the southern border of the Cowee quadrangle. One of the prettiest and most typical of the group is found in the "Pink Beds" in the north central part of the Pisgah quadrangle. Others are found along the Blue Ridge scarp on the same map. The writer believes that there are at least three possible explanations that may be offered for these features, and that examples of all three types may be found.

In the case of those high-lying mature valley heads along the Blue Ridge, stream piracy is the most plausible explanation. The application of this idea will be made in later paragraphs. In addition to the writings of Davis and Johnson where this point is discussed, Keith (60) draws special attention to this type of feature in his "Physical Geography of Georgia." "A few valleys in the Blue Ridge reverse the usual rule and have

broad, open upper reaches and steep narrow gorges in their lower parts. They are associated with the plateaus and are typical 'hanging valleys,' indicating that their streams have been captured and diverted. The most striking of these is on Amicalola Mountain, where a stream flows with a gentle grade for 2 miles, and then pitches abruptly down the mountain for 500 feet and forms Amicalola Falls, the most picturesque in the Blue Ridge. Similar but larger is the valley of Mud Creek, an eastern tributary of Little Tennessee River. This flows in an open plateau valley for three miles and then tumbles 500 feet into a narrow chasm; thus is formed Estatoah Falls, the second principal fall in the Blue Ridge. The largest example of this is Tallulah Falls. Above the Falls the entire River lies on or above the Dahlonega Plateau, but at that place the stream drops 700 feet in two miles into a deep chasm in the Plateau. The River bed is lined with falls and rapids, and the most noted is shown in the Frontispiece, Plate I."

The present writer is quite in accord with Keith's interpretation of Amicalola Falls and Tallulah Falls, but he is inclined to raise a question concerning Estatoah Falls on Mud Creek, a photograph of which is reproduced in Plate LII.

The second theory which may be applicable to these high-lying mature basins above falls and gorges may be found in the general thesis of this part of the present paper. That is to say, the Harrisburg level may still be preserved in some of these basins because the hard rock barrier has delayed the work of erosion following rejuvenation. The erosion surface above the barrier has remained undissected because the impetus of rejuvenation has not yet extended up into this portion of the valley. "The Glades," an apparent remnant of the Harrisburg level in the Valley River basin doubtless provides an illustration of this sort. Welch Creek crosses a single contour in three quarters of a mile, and then crosses four more in half that distance. The barriers which hold up these local mature valley heads are of quite variable resistance, and consequently we find all stages between the sharply marked cases, such as have been referred to, and those that because of a relatively weak barrier have lost some of their original flatness.

The third explanation which the writer would like to present was suggested by Professor Johnson and is applicable only to localities underlain by extremely weak rock. Where a stream is situated on rocks of very low resistance, it is quite possible that its valley will be graded to the open mature form just as rapidly as the outlet stream cuts down through the barrier of hard rock. The writer in traversing the belt known as "The Pink Beds" on the Pisgah quadrangle was impressed by the unusual flatness of the present valley floor, over 3200 feet above sea level. On the basis of elevation Keith in the Pisgah folio correlated it with the "Plateau of the Blue Ridge," which was the oldest of the three erosion levels recognized by him in this region. Although the interstream meander spurs along the course of South Fork, the outlet stream of this basin, appear to rise upstream to attain the level of the floor of "The Pink Beds," it is possible that this valley floor may not be related to the Harrisburg or any other peneplane. The resistance of the rocks underlying this basin is so low that this part of the valley may have been reduced to a mature form which is maintained at gradually decreasing levels as the outlet stream cuts down.

The writer has seen examples of these high-lying basins and mature valleys above falls or rapids in the Appalachian Plateau to the west, and in various parts of the Older Appalachians almost as far north as the Potomac River. Detailed local studies may find the applicability of these three, and possibly other interpretations.

The head of Little Tennessee River in northern Georgia is not against a marked divide. The basin of Stekoa Creek extends to the south and the divide between the two streams is extremely flat. It is one of the two places, as pointed out by Keith, where it is possible to pass from the highland down to the lower level of the Dahlonega Plateau without a step descent. The same author points out that the Tennessee River has lost a part of its territory to Stekoa Creek. This fact will be elaborated on a later page.

The Harrisburg level is developed and preserved almost continuously along this stream from Bushnell, where it is joined by

the Tuckasegee, up to its very head. It is especially well shown in the vicinity of Franklin, N. C., in the western part of the Cowee quadrangle, as shown in Plate LIII. The elevation of the surface rises from approximately 1600 feet at the North Carolina-Tennessee line up to 1800 feet at the junction of Tuckasegee and Little Tennessee Rivers. From this point to the head of the stream, a distance of over 40 miles, it rises only 300 feet. It will thus be seen that the slope of this surface is lower than that observed thus far in any other basin. It is also true that it is the longest strip of Harrisburg surface that we have examined.

Cullasagee River, entering the Little Tennessee at Franklin, North Carolina, flows over a fall involving three contours. These falls (Plate LIV), seem to have no relation to either a Harrisburg basin or a mature valley upstream. There is a young gorge below and above the falls which are located about eight miles southeast of Franklin. We find, however, far upstream near Cowee Gap an open country which extends as far as the village of Highlands. This may represent one of the three types of basins previously described.

The author considers the basin of Little Tennessee River, in its present form, as largely the result of stream erosion in the cycle just preceding the present. It should be borne in mind that the courses of many of the lateral tributaries were never graded in that cycle and that the mountain groups bordering the more open central part of the basin rise either to the Schooley or to an undetermined earlier level. The belt of hard rocks which constitute the last barrier on the west before entering the Appalachian Valley, was not as formidable in the case of this stream as in some of the others. It is believed that traces of the mature valley in this hard rock area can be identified with reasonable certainty.

The Pigeon Basin

The Great Smoky Mountains lie to the north of the Little Tennessee River and constitute an imposing barrier to the westward flowing streams. There is no break in this range until we

come to the valley of Pigeon River which cuts across the barrier at Waterville on the North Carolina-Tennessee line. Pigeon River has its source on the northwest slope of Pisgah Ridge which forms the boundary line between Haywood and Transylvania Counties in North Carolina. The east slope of this ridge drains to the French Broad River. The East and West Forks of Pigeon River, flowing to the northwest and north respectively, unite at Sonoma to form the Pigeon River. Thence it flows northward to Canton where it turns sharply to the west. From Clyde, four miles west of Canton, it flows in a northwesterly course until it joins French Broad River, about five miles north of Newport, Tennessee. Its basin is shown on the Pisgah, North Carolina-South Carolina, Asheville, North Carolina-Tennessee, and Mt. Guyot, Tennessee-North Carolina topographic maps. The best development of the Harrisburg surface is found on the Asheville quadrangle. Around Newport, Tennessee, the Valley Peneplane has an elevation of approximately 1200 feet at the present time. A broad extension of this surface continues up the Pigeon River between English and Stone Mountains. Along the course of the stream through the resistant rock belt forming the Great Smoky Mountains few traces, if any, of the Harrisburg level may be found on the map. The stream has an apparent meandering course through this district, but the intermeander spurs are high and may not represent the work of the Harrisburg cycle. Traces of the level appear on the upstream side of the Great Smoky barrier on the eastern margin of the Mt. Guyot map. It is also found in the valley of Jonathan Creek, a tributary of Pigeon River, located in the extreme southeastern corner of the same map. On the main stream at the western margin of the Asheville quadrangle, the local peneplane appears at an elevation of approximately 2600 feet. It rises upstream to a height of 2700 feet near Clyde. A prong of the basin extends up Richland Creek beyond Waynesville where it reaches an altitude of approximately 3000 feet. Around Waynesville it is about 2800 feet. It ascends up the main valley to 2750 feet at Canton, beyond which it gradually rises to 2800 and 2900 feet in the valleys of the East and West Forks. Notwithstanding the rela-

tively small areal extent of Harrisburg surface in this basin, it reached a rather perfect stage of development. A view looking across this basin between Clyde and Canton may be seen in Plate LV and a longitudinal view is shown in Plate LVI.

Richland Creek has been artificially dammed near Tuscola to produce a large lake called Junaluska. The accordant hills rising about 200 feet above the level of the lake, which sends arms up the valleys between the hills, are very beautiful. It is interesting to note that so many of the artificial lakes in the crystalline area have been made in areas where the Harrisburg level was well-developed. The drowned tributary valleys between the projecting spurs are indeed picturesque. In addition to Junaluska, one could mention, among others, Lake James near Morganton, Lake Lure at Chimney Rock, and former Lake Toxaway in the southwestern part of the Pisgah quadrangle.

In various parts of the Older Appalachians there is a linearity of trend of drainage lines. This is interpreted on the basis of structural control, due to the strike of the rock formations or to faulting. The West Fork of Pigeon River, Pigeon River, North Fork (Hominy Creek), and Newfound Creek, all of which trend northeast and southwest in a linear fashion, provide an illustration of structural control.

Perhaps the most unique feature associated with the drainage of this basin is the piracy effected by Hominy Creek near Canton, North Carolina, as first pointed out by Harris in 1893, and later described by the present writer (82). Hominy Creek has pushed back the divide between the French Broad and Pigeon River basins from its former position, near the Haywood-Buncombe County line, about four miles, to its present position in the village of Canton. It is a very pretty example of drainage change because the evidence is still beautifully preserved. In this connection, it is interesting to note that the head of Newfound Creek, a tributary of the French Broad, southeast of Rockyface Mountain, is pushing westward the divide in the direction of Pigeon River. The prime cause for the instability of the Pigeon-French Broad divide is the disparity in elevation between the two basins. The Harrisburg level in the French Broad is approximately 2350

feet above sea level just east of the former divide at the County line, whereas the Pigeon River level is about 2750 feet on the opposite side. The gravels on the divide at Canton are unusually large and well rounded.

By reason of this reversal in direction of flow of the tributary of the Pigeon River entering at Canton, there is a very striking contrast in the gradient of the streams east and west of Canton. The 2500 foot contour is crossed by the eastward flowing stream within a mile, whereas the same contour is crossed by the Pigeon River more than seven miles to the west. By reason of this difference in slope the head of Hominy Creek is vigorously engaged in cutting away the divide at Canton and will shortly divert the entire upper Pigeon River into the French Broad. As a matter of fact it would seem to be a relatively simple matter to produce this result artificially.

The Pigeon River basin possesses all the characteristics of the basins previously described, and it seems to have had the same erosional history. It is not as definitely connected with the peneplane of the Appalachian Valley as the others. The intrenched meanders through the rocky barrier of the Great Smoky Mountains may date from a cycle earlier than the Harrisburg. The district is rather inaccessible and the writer has not been able to visit this part of the Pigeon Valley. The Mt. Guyot map on which the middle and lower parts of the course of this stream appear is an early one, and the features are not brought out as clearly as they are on the Asheville map to the east. It is possible that more traces of the former mature valley exist than are shown on the map.

The Nolichucky Basin

The Nolichucky River joins the French Broad less than five miles below the union of the French Broad and Pigeon Rivers a short distance north of Newport, Tennessee, on the Morristown, Tennessee, topographic map. The lower part of the Nolichucky in crossing the Appalachian Valley takes a westerly course. It emerges from the Older Appalachian Mountains a half dozen miles south of Jonesboro, Tennessee, on the Roan Mountain

quadrangle. The main headward tributaries are the North and South Toe Rivers, which drain the territory between the Black Mountains and the Blue Ridge, and Cane River, which has its basin in a district lying west of the Black Mountains. The two Toe rivers unite in the northern part of the Mt. Mitchell quadrangle while the Cane joins the combined North and South Toe Rivers, called the North Toe, near the southern border of the Roan Mountain quadrangle. Below this point the main stream bears the name of Nolichucky. The Mt. Mitchell and Roan Mountain topographic maps cover the area to be described.

An erosion level, which is interpreted as the Harrisburg, appears to be well developed in the valleys of Cane, South Toe, and North Toe Rivers. The elevation of the Valley Peneplane at the point where the Nolichucky enters the Valley is approximately 1600 feet. It is traced upstream to Erwin where it occurs between 1700 and 1800 feet. As a former mature valley it apparently can be traced up North Indian Creek perhaps as far as Limestone Cove. It is also represented in the valley of South Indian Creek. These two streams enter on opposite sides of the Nolichucky near Erwin and doubtless owe their alignment to a belt of weak rock. For a distance of perhaps ten miles above Erwin the present stream flows in a narrow valley through the Unaka Mountains. There appear to be occasional traces of the former valley through this barrier in the form of intrenched meanders and benches. At the point where the Cane enters the North Toe near Huntdale the much dissected Harrisburg seems to be preserved at an elevation of 2300 to 2400 feet. Cane River here has a broadly intrenched meandering course, and the meanders are well developed for a distance of about fifteen miles. Between the villages of Burnsville and Bald Creek the writer was especially impressed by the accordancy of hills at an altitude of 2800 to 2900 feet bordering the present valley of Cane River. These hills rise about 200 feet above the present valley floor and represent a very much dissected erosion surface. On one of these hills there were found large numbers of gravels, some of which were well rounded. They were composed of quartz, gneiss, and other local rocks. These gravels may or may not be related to

the Harrisburg surface, the uncertainty being due to the lack of a more accurate determination of their position with reference to this surface. The level, however, can be traced southward along the Cane River to the vicinity of Big Tom Wilson's where it reaches a height of at least 3000 feet. This is one of the first localities where the writer in his notes, some years ago, compared the topography with that of the intermontane valleys in the Newer Appalachians where there are traces of the Valley erosion surface.

The valley of the South Toe exhibits very clear evidence of erosion in a former cycle, which certainly cannot be farther removed than the Harrisburg. Where it joins the North Toe, we find the erosion surface at a present elevation of approximately 2600 feet. It should be borne in mind with reference to these elevation figures that they are usually taken from localities near but not at the stream. Slightly higher values can be gotten by taking the elevations from the margins of the basins. The slopes rise up the main and tributary streams. Altitudes taken from the upland close to the stream are apt to be too low, because of erosion in the present cycle. The upstream rise of the Harrisburg level in the South Toe valley is about 400 feet in about a dozen miles. In the vicinity of Micaville, it is especially well developed, and the chain of intrenched meanders above and below this point are among the best in the Appalachians. Even in the tributary valley of Little Crabtree Creek which rises just north of Burnsville and flows eastward to join the South Toe at Micaville, we can see a series of accordant hills as shown in Plate LVII. Browns Creek, a small stream entering Little Crabtree Creek near Micaville, has an unusually open Harrisburg basin. Another view, which looks across the accordant Harrisburg level, is shown in Plate LVIII. It was taken from the base of Little Celo Mountain looking north across a bend in the South Toe River. The present stream is so sharply intrenched in this surface that it is completely hidden from view.

North Toe River has its source against Sugar Mountain west of Grandfather Mountain. In its upper course, near Old Fields, it has an open basin at an elevation of 3600 to 3700 feet. The

best record of Harrisburg erosion is found from Plumtree on the Roan Mountain quadrangle down to the point where it is joined by the South Toe. It is particularly well shown in the area between Sprucepine and Mica and between Sprucepine and Elsie. The intrenchment of the stream in a series of winding meanders is well brought out here. From a point four miles northeast of Sprucepine, a splendid view of this surface is seen at an altitude of 2800 feet, or slightly above. The accordant wooded hills in Plate LIX represent this level. In the background to the left is Doe Hill Mountain and on the right Humpback Mountain. Between the two mountains the skyline is formed by the rim of the Linville basin where the level developed in Harrisburg time stands at an elevation of approximately 3300 feet, or nearly 500 feet above the corresponding level in the contiguous North Toe basin. An unusually well-developed area of Harrisburg country is seen in the valley of Rockhouse Creek which drains the area around Mica and enters the North Toe River about a mile south of Sprucepine.

The Nolichucky River appears, therefore, to have had in the cycle preceding the present, a history similar to those of the other westerly flowing streams which have been described. The features of the present topography in this basin are in all essential respects like those in the other basins. This stream has been and still is losing drainage area to the Atlantic flowing streams. Professor Davis in his "Stream Contest Along the Blue Ridge," describes in particular the progress made by Bee Rock Creek and other eastward flowing streams in abstracting territory from the South Toe River. The North Toe has also been a loser in competition with the Atlantic Streams gnawing back into the Blue Ridge scarp, and it is possible that it had in Harrisburg time a considerably larger drainage area as will be pointed out on a subsequent page.

The Doe and Watauga Basins

The Doe River drains an area in Carter County, Tennessee, and unites with the Watauga at Elizabethton, Tennessee. The Harrisburg level is apparently well developed between

Elizabethton and Milligan and traces of it occur in the subsequent valley east of the Iron Mountain-Gap Creek Mountain ridge northeast and southwest of the village of Hampton. In addition, there are some open mature valley heads such as Roaring Creek which may or may not be related to the Harrisburg cycle. There are no open expanses of Harrisburg country in this basin.

Watauga River has its head against the northern slope of Grandfather Mountain, and drains a large area in Watauga County, North Carolina. Elk Creek rises against the western slope of Grandfather Mountain, drains the northwestern corner of Avery County, North Carolina, and enters the Watauga River a half dozen miles west of the North Carolina line. The presence of a former mature valley along Banners Elk Creek, main stem of Elk Creek, in the vicinity of Banners Elk may be seen. In general, however, the writer was not impressed with the evidence of Harrisburg erosion in this valley, but the examination was quite brief. The Watauga River valley seems to have traces of the Harrisburg level, especially near Vilas and Valle Cruces, but there are no large areas. In the Tennessee part of the basin, however, the streams which occupy the soft rock belts trending northeast and southwest, did develop in Harrisburg time an erosion level which is well preserved. This may be seen in the valley of Roane Creek at Vaughtsville, in the valley of Town Creek near Mountain City, in the valley of Doe Creek around Doeville and Pandora, and also in the valley of Stony Creek.

The Linville Basin

The Linville River differs from the streams which we have been considering in that it flows eastward to the Atlantic. We are concerned here with only the upper part of its basin, from Linville Falls to its head on the southwestern slope of Grandfather Mountain. This involves a strip of country lying along the Blue Ridge scarp about five miles in maximum width and twelve to fifteen miles in length. Although the name Blue Ridge is printed on the map along the western margin of this

basin no real escarpment exists there. The true Blue Ridge is actually on the eastern side of this basin and the Linville River crosses the upper part of it at Linville Falls.

For a short distance below this point the stream flows in a deeply intrenched meandering course down the steep gradient that is common to streams which drain the Blue Ridge scarp. Linville River flows into Catawba River between Marion and Morganton. Its lower course lies in the Catawba lowland, a broad area of Piedmont country between South Mountains and the Blue Ridge. The features of this basin are represented on the Cranberry, North Carolina-Tennessee, and Morganton, North Carolina, topographic maps.

Because of its unusual location along the Blue Ridge scarp and because of the eastward direction of flow of its master stream, the Linville basin is unique among these high-lying local peneplanes. It is quite improbable that this surface was developed by a stream which flowed in the direction of the present Linville River. This aspect of the problem will be dealt with in the section devoted to drainage changes. This locality is also unique in that it is the highest in elevation of any of the Harrisburg basins. Just above Linville Falls it is approximately 3200 feet above sea level, at Altamont about 3300 feet, near Pineola between 3700 and 3800, and approximately 4000 feet at Linville. The former mature valley extends farther upstream at this level for some miles. A photograph of this surface, as seen near Pineola, is reproduced in Plate LX.

This erosion surface obviously represents the work of the Valley cycle, but because of the retreat of the Blue Ridge scarp into the basin, the position of the lower course of the former stream is in doubt. Nevertheless, the writer sees no reason for assigning to this basin an erosional history different from those of the westward flowing streams previously described.

The New Basin

All of the streams, except the Linville, whose basins have been described on the preceding pages, flow to the west and enter the Appalachian Valley, where they join other streams which

flow to the southwest to form the Tennessee River. The New River, on the other hand, flows into and across the Appalachian Valley, then through the Allegheny Ridges and finally into the Appalachian Plateau, where it unites with the Gauley to form the Kanawha River. It is probable that the New River has today much the same course that it had in the Schooley cycle. It is also probable that the upper courses of the other streams in the Older Appalachians date from that cycle. At some later time they were diverted to a southwesterly direction in the Great Valley. The position of the New River across the Appalachian chain indicates, in the absence of any overlying cover from which it might have been superposed, a very early origin. Indeed it may be an antecedent stream, antedating the Appalachian folds. At any event, there is no suggestion of a change in its direction of flow during the erosional period of the history of the Southern Appalachians. Because of this, as well as the further fact that the New River traverses three great physiographic provinces, it should be expected to throw important light upon the erosional history of a large area of country.

The New River drainage area to be discussed in the succeeding paragraphs is represented on the following topographic maps of the United States Geological Survey: Cranberry, North Carolina-Tennessee; Wilkesboro, North Carolina; Wytheville, Virginia-North Carolina; Hillsville, Virginia-North Carolina; Dublin, Virginia-West Virginia; and Big Bend, Meadow Creek, Beckley, and Fayetteville, West Virginia.

The main stem of South Fork of New River rises at Blowing Rock, about ten miles east of Grandfather Mountain, and flows to the north. Within ten miles of its head one may see unmistakable evidence of its former mature valley about two miles east of Boone, North Carolina. At this point the stream is intrenched below the former level which has an elevation of approximately 3200 feet. In the picture reproduced in Plate LXI we can see the accordance of the hilltops in the background, the slip-off slope in the left middle distance, and the modern floodplain in the foreground. South Fork of New River flows for a considerable distance just west of the Blue Ridge scarp.

Its intrenched meanders, with strikingly accordant intermeander spurs descending downstream, give a clear impression of the topography as it existed at the close of the Harrisburg cycle. It will be remembered that the Schooley level is represented here at an elevation of approximately 3500 feet. At Deep Gap on the eastern margin of the Cranberry quadrangle, there is a broad open basin near the very head of a small stream called Gap Creek. Cleared fields apparently represent the level of the stream in Harrisburg time about 80 feet above the present valley floor while the skyline seems to preserve the Schooley level at an altitude of 3500 feet. North Fork of New River, draining the northeastern corner of the Cranberry quadrangle, has apparently intrenched itself into its Harrisburg surface to approximately the same extent as the South Fork.

On the Wilkesboro, North Carolina, quadrangle, South Fork has thrown itself into a series of extravagant meanders. North Fork has only a small representation on this map, but its testimony is precisely the same. The Harrisburg level at the western margin of the map in the valley of South Fork stands at an elevation of approximately 3100 feet, and it descends 300 feet in crossing the Wilkesboro quadrangle. The tributary streams in this region also were able in the former cycle to bring their valleys down to grade. Special mention might be made of Naked and Mulberry Creeks, and Little River which enters New River on the Wytheville map. It is interesting to note that the New River lowland of Harrisburg time has been cut into by the retreat of the Blue Ridge scarp in the area north of Horse Gap, so that the crest of the Blue Ridge is at this point not Schooley, but Harrisburg in age.

Identically the same evidence of Harrisburg erosion that was found upstream in the basin of New River can easily be traced on the Wytheville, Virginia-North Carolina, and the Hillsville, Virginia-North Carolina, topographic maps. Its elevation south of the Farmer Mountain-Poplar Camp Mountain ridge, through which it breaks to enter the Appalachian Valley, is 2500 feet. From this point, it rises upstream along the course just traced to an elevation of about 3200 feet opposite Boone. Traces

of the former mature valley rise rather steeply upstream from this point to a height of more than 3500 feet. This statement is supported by field observation, map representation, and extensive profiles. The profiles show the gradual rise of the Harrisburg lowland from the northern margin of the crystalline area almost to the head of the river.

The Hillsville region is characterized by accordance of hilltops. In view of the diversity of rock types in this district, it is ordinarily regarded by physiographers as an example of a fairly perfect peneplane. When we follow up the valleys of the four main tributaries of New River which drain the Hillsville area, we note a rather interesting relationship. Beginning on the west these streams are Chestnut, Crooked, Reed Island, and Big Reed Island Creeks. The same type of topography is apparently developed in the basins of these streams as in the case of the New River itself. The erosion surface rises from the level of the New River basin gradually upward to a height of almost 2700 feet, in the case of Big Reed Island Creek. On an earlier page it was pointed that the Schooley level stands at an elevation of approximately 3100 feet on the Blue Ridge scarp and on some of the divides extending northwestward between these creeks. It appears to be represented also on Indian Ridge and on Mack's and Poplar Camp Mountains. It is impossible to give a very accurate estimate of the present elevation of the Schooley surface because of its fragmentary preservation in this area. The writer suggests that the lower peneplane developed in the Hillsville locality was formed in Harrisburg time. By referring to Plate LXIII one may get an impression of the evenness of the surface as seen from the highway about one mile south of Hillsville, while in Plate LXIV he may see the more dissected character of the same level, about one and a half miles north of Hillsville, near Reed Island Creek.

If the above interpretation is correct a clear impression of the erosional history of this district may be gained by examining Plate XXXV. This view looks northeast from a point on the highway between Chestnut Creek and Crooked Creek, and shows a broad expanse of Harrisburg country extending to Hillsville.

On the right the Schooley Peneplane is preserved on the Beamer Knob-Pike Knob divide several hundred feet higher than the Harrisburg.

The New River below the Poplar Camp Mountain barrier flows northeastward in a subsequent course along the limestone belt of the Appalachian Valley to the city of East Radford, a distance of about thirty miles. Here it turns to the north, and, after flowing through several broad and graceful intrenched meanders, pierces the first of the Allegheny Ridges. These features are shown on the Dublin topographic map. The Valley Peneplane has an elevation of 2300 to 2400 feet where the New River enters the Valley and it slopes downstream until in the vicinity of Walker Mountain, the first of the Ridges, it stands at a height of approximately 2100 feet. There seems to be no question about the unity in the later erosional history of this section of the Valley and the Older Appalachians. All lines of evidence point to the continuation of the Valley Peneplane upstream into the crystallines, and it is believed that the evidence is sufficiently trustworthy to tentatively regard the Valley Peneplane and the corresponding erosion surface in the Older Appalachians as of the same age. The relationship between these two surfaces, which have ordinarily been regarded as belonging to distinctly different cycles, is brought out more clearly here than in any other locality which we have considered. The reason is probably to be found in the narrowness of the hard rock barrier on the northwestern side of the crystalline belt, and probably also the only moderately resistant character of the schists in the Hillsville region. It would appear that this is a case where in a single cycle a higher erosion level is carved on more resistant schists and a slightly lower level on weak limestones by streams which pass from the former to the latter across a resistant barrier. The barrier alone should cause a difference in the peneplane level, but when in addition there is a rock contrast in the two areas, the discrepancy in levels has a double cause, adequate to account for the difference without invoking an extra erosion cycle.

Let us now consider briefly the features of the New River as it passes through the Ridges. Here we find intrenched meanders

with intermeander spurs preserving the ancient floodplain at a nearly uniform level, which varies little from 2100 feet through the fifteen mile belt of ridges. Furthermore, the subsequent tributaries, which enter the New River in this part of its basin, brought their basins to the same level in Harrisburg time. This is particularly well shown in the valley of Walker Creek. The belt of Harrisburg country is five or six miles wide in the Pearisburg locality. Except possibly in the constricted part of the stream just north of Narrows, there is abundant representation in this belt of the Harrisburg erosion level.

In order to attempt a tentative correlation of the erosion cycles in the Older Appalachians with those of the Appalachian Plateau, we will now trace the New River as far as its junction with Gauley River at Gauley Bridge. Through the northern part of the Dublin map and the southern section of the Hinton sheet the New River follows a winding course through a rather open but much dissected region. Several typical Harrisburg areas lie to the west of the stream. The district around Princeton, West Virginia, is representative of the group. The Bluestone River also, to the northwest of Princeton, developed an open basin in the Valley cycle and now flows through a series of intrenched meanders. The elevation of the peneplane in this district appears to be about 2500 feet.

New River is joined by Greenbrier River a short distance south of Hinton, West Virginia. The topography in this locality is very rugged and gives relatively little suggestion of definite erosion levels. It is apparently higher than the Harrisburg level but lower than the Schooley. From Cemetery Hill, east of the city, one may get a good view of White Oak Mountain, the top of which apparently preserves the Schooley Peneplane at an elevation of more than 3000 feet. Southeast of Hinton near Big Bend there seems to be a general accordance of hilltops on both sides of the river at a height of approximately 2000 feet. New River north of Hinton flows through a very deep and steep-walled gorge until it reaches Gauley Bridge. The canyon in the lower stretch is not as deep as it is farther upstream, where it reaches a depth of 1300 feet. It is one of the finest examples of a canyon

in the eastern United States. It is followed by the Chesapeake and Ohio Railroad and the views from the train windows are picturesque. It is seen to excellent advantage from numerous points along the rim, as at Hawks Nest. This section of New River is shown on the Fayetteville, Beckley, and Big Bend, West Virginia, topographic maps.

The writer was greatly impressed with the Harrisburg surface in the soft rock country shown on the Fayetteville and Beckley maps. Near Fayetteville it has an altitude of approximately 1900 feet, while farther south near Beckley it rises to a height of nearly 2500 feet. It should be borne in mind that these localities are west of the Allegheny Front and lie within the heart of the general area where the Schooley Peneplane is best preserved. The streams which drain these high basins have open valleys near their heads, but they flow through narrow gorges in their lower courses. Near Beckley, for instance, where the Valley surface is well developed, the streams are not sharply intrenched below that level, but in a relatively short distance they descend into gorges which reach depths of almost 1000 feet where they join the New River.

Campbell described in the Raleigh Folio two erosion levels in this area. The older one, Cretaceous in age, "would now be about 3500 feet above sea level at Flat Top Mountain, which is located on the southeastern margin of the coal field. . . . . Therefore the surface which presumably corresponds in age with the Lexington Plain rises from 2000 feet at Oak Hill to 2500 feet at Beckley and 2700 feet in the southeastern corner of the quadrangle. In the vicinity of New River and in the Guyandot basin this feature is generally well developed, but in much of the intervening territory the surface is broken by ridges of various heights, which are the remnants of the higher plateau."

It does not come within the scope of the present paper to attempt a further tracing of the Harrisburg level down the Kanawha Valley to the Ohio River. The writer would like to point out, however, that in the strip of high country lying just west of and including the Allegheny Front, the Schooley Peneplane appears to be fairly well preserved, because of the great

resistance of the rocks. The Schooley Peneplane was not as perfect a surface as it has sometimes been considered, and its perfect restoration after long erosion is extremely difficult. It is believed by the present writer that most of the forms in the topography west of the belt along the Allegheny scarp were produced in the Harrisburg cycle and that the Schooley level has little preservation in the western part of West Virginia. In an earlier report (79) he drew a contour map to show the restored Upland Peneplane. On this map the present remnants of this surface slope steeply to the west. In general this is true, but it is now believed that the lower elevations in the northwestern area belong to the Harrisburg rather than the Schooley level. In that area the older surface has probably been removed by erosion rather than downwarped to form the present accordant hilltops. This would seem to be the case in Gilmer and Braxton Counties, West Virginia, where the peneplane is preserved on accordant hilltops at elevations varying from 1500 feet on the east to 1200 feet on the west. The beautiful intrenched meanders of the Elk River near Sutton and those of the Little Kanawha above Glenville strongly suggest the development of this peneplane in Harrisburg time.

Summary of Description of Harrisburg Erosion Remnants

We have just traced the major streams of the Older Appalachians and have attempted to point out the extent of the development of the Harrisburg or Valley erosion level. From a study of the maps as well as from observations in the field, the writer believes that the so-called Harrisburg cycle left a very significant and widespread imprint upon the topography of the Southern Appalachians. He does not claim that the cycle began and ended at the same time in all parts of the region. It would add to the understanding of this area if we could correlate the features at widely varying elevations which were formed during this cycle.

Correlation of the Harrisburg Remnants

In an earlier paper (81) the author pointed out the possibility of assigning the Asheville and other high-lying local peneplanes

to the cycle during which the Appalachian Valley Peneplane was formed. Now that additional studies have been made, he is still inclined to the same view. In the description of the river basins the connection between these high-lying local features and the extensive Valley erosion level has been pointed out. It is not necessary to review again these facts. In the essay referred to above, the correlation of these surfaces was made on the basis of: (1) extent of development, (2) degree of dissection, (3) elevation above sea level, (4) water-worn gravels, (5) drainage lines. In addition to these considerations, it should be added that one of the most convincing lines of evidence is the tracing of the higher levels down to the lower ones. In some instances the connection is rather uncertain while in others, as for example the New River, it seems to be undoubted.

The writer rather cautiously suggested also the possible correlation of these high levels with the Piedmont. In view of the fact that the Piedmont lies within the Atlantic drainage, while the other basins with few exceptions drain to the Gulf, and the further fact of great difference in elevation on the two sides of the Blue Ridge, it seems difficult to support such a correlation. It is still the conviction of the writer, however, that there is some strong evidence in support of this interpretation. A few localities have been selected which show typical relationships between these erosion levels and they will be considered in the following pages. In some cases the relationship is between the Piedmont and the Valley while in others it is between the Piedmont and the high-lying levels. In view of the fact that we have support for the correlation of the Asheville and similar levels with the Valley, it would be interesting to see what relation the Piedmont has to the Harrisburg surface as it is developed in the Appalachian Valley and Older Appalachians.

The Roanoke Basin

The Piedmont Peneplane stands at an elevation of approximately 1000 feet in the open Piedmont country adjacent to the Roanoke River southeast of Roanoke, Virginia. Some distance back from the stream, especially near the base of the Blue Ridge,

it stands at an elevation of 1100 feet or above. This level is clearly traceable through the break in the Blue Ridge at Roanoke. The extremely flat character of the topography north and west of this city would suggest the possible occurrence here of a lower level, such as the Coosa. The general level, however, rises up the valley of Roanoke River as well as up the valley of Tinker Creek. Excellent Valley topography occurs in a broad area centering around Fincastle. The same surface can also be traced up the valley of Glade Creek by Bonsacks and Coyners almost to the very head of the stream at Blue Ridge Springs. Here we cross a low divide and enter the valley of a tributary of Goose Creek. North Fork of Goose Creek, a tributary of Roanoke River, has an open basin which lies behind Taylors Mountain, a part of the Blue Ridge. The presence of these extensions of the Piedmont surface such as that in the basin of Goose Creek, back into the Blue Ridge Mountain, not only indicates unity in the erosional history, but also discredits the marine theory of origin of the Piedmont.

The rise of the erosion level up the Roanoke River is quite similar to that of other Harrisburg basins. The Roanoke branches at La Fayette. South Fork has its head in Bottom Creek against the eastern slope of Poor Mountain in the Older Appalachians. North Fork has its source north of Paris Mountain where the Valley Peneplane is developed at an elevation of 2200 feet. This stream flows southwest, south and then northeast, while the South Fork flows southwest, then north, and finally northeast. There is a very sharp break in the slope between the New and Roanoke River basins. There is a steep ascent as one goes southwest toward the New River. The peneplane on the divide is broadly developed at an elevation of 2200 feet, while the Roanoke basin reaches an elevation of only 1600 or 1700 feet. As a result of this difference in elevation the tributaries of the Roanoke are pushing the divide toward the basin of the New. In view of the fact that the entire upper basin of North Fork is characterized by an erosion surface at 2200 feet in elevation, which slopes toward the New River basin and was evidently developed by that stream, and the further fact that the stream makes a

sharp bend in its direction of flow, we are justified on map evidence alone, in suggesting the strong probability that capture has taken place. The same is likely true of South Fork. There seems to be no reasonable ground for giving the Piedmont surface below Roanoke a different date from that of the Valley Peneplane. The relationship between the Roanoke and New basins, furthermore, is quite similar to that between the Asheville and Pigeon River basins. At the close of the Valley cycle they stood some 500 feet apart, and this fact has been responsible for a shifting of the former divide in the present cycle. The difference in elevation of the peneplanes produced during the Harrisburg cycle here as elsewhere was due chiefly to difference in distance to the sea and the presence of resistant barriers downstream. Subsequent warping, as proposed by Campbell (9), may have been a factor.

The Catawba Basin

A comparison of the Asheville and Piedmont Peneplanes was made many years ago by Kerr (57). The interpretation placed upon these two erosion levels by Hayes and Campbell was that they represent one and the same surface, the Cretaceous Peneplane, the difference in altitude being due to warping. The author now believes that they are Harrisburg in age and that their downstream slope is original and not primarily due to warping. At Old Fort, about ten miles southwest of Marion, North Carolina, where the Catawba lowland is very narrow, the Piedmont level has an elevation of almost 1600 feet. The former mature valley can be traced up the Catawba River and also along Crooked Creek to an altitude of approximately 1800 feet. As already noted, the Asheville surface along the Swannanoa River is not over 2400 feet in height at Black Mountain just west of the scarp. The difference between the level in the Swannanoa basin in the upland and the higher remnants of the Piedmont level is not more than 600 feet in this locality. In view of the enormously greater length of the streams which flow to the northwest, this difference in level is not one that should offer serious difficulty in the classification of erosion forms. It should be

pointed out that the Catawba lowland is a broad arm of the Piedmont behind South Mountains.

The Chattahoochee Basin

One of the most interesting areas in the Southern Appalachians lies in northern Georgia. It includes a section of the Older Appalachian upland with the Blue Ridge scarp as its southern border, a belt of peneplaned crystallines sloping to the southwest between the Blue Ridge and Chattahoochee escarpments, and lastly the contiguous portion of the Piedmont southeast of the Chattahoochee escarpment. The streams in the highland flow by way of the Tennessee River into the Gulf of Mexico, those of the intermediate Chattahoochee level, except the Tallulah, go directly to the Gulf, while the rivers of the Piedmont flow eastward to the Atlantic Ocean.

In a paper published in 1907, Johnson described the Chattahoochee and Piedmont levels and dealt at length with a piracy problem in the Tallulah district. He showed how the Tugaloo River from its lower level on the Piedmont gnawed back into the Chattahoochee basin and abstracted the headwaters of Deep Creek, a member of the Chattahoochee system. Chattooga River is the captured stream.

LaForge has described this part of Georgia in "The Physical Geography of Georgia," published in 1925. The reader is referred to this volume for a very interesting and complete description of the physical features of the state. Reference has already been made to Keith's descriptions of the Highland in the same bulletin. LaForge divides the Central Upland into two parts, Midland Georgia and Piedmont Georgia. The former, also called the Midland Slope, east of the Chattahoochee escarpment, has been called Piedmont by Johnson and others. Piedmont Georgia, according to LaForge, includes the Dahlonega Plateau, the Atlanta Plateau, and the Tallapoosa Upland. The Dahlonega Plateau of this writer is the upper Chattahoochee basin and lies at the base of the main Blue Ridge. At the present time we are concerned with the Highland, which has already been described, the Dahlonega and Atlanta Plateaus, which

we will here call the Chattahoochee basin or level, and the northwestern corner of the Midland Slope, for which the name Piedmont will be used.

In order to have in mind the essential physical features of the region, a few words of description may be in place. The upland, which forms the southernmost part of the Older Appalachians, comprises a series of basins whose floors are at elevations of 2000 to 2100 feet, separated by mountains of variable height. The divides are irregular in trend and not readily classified on a basis of genesis or altitude. As previously explained, these basins are assigned to the Harrisburg erosion cycle, while the mountains represent residuals rising above this surface, as well as remnants of the older peneplane itself. The southern margin of this elevated country is formed by the Blue Ridge, an irregular feature extending in general from east to west, but slightly south of west. At many points it is surmounted by peaks such as Tray Mountain (4398 feet) and Blood Mountain (4463 feet). The skyline between these eminences is not characteristically even, but it does leave that impression when viewed from some points on the Chattahoochee level below.

South of the Blue Ridge, the Chattahoochee level is a magnificently developed peneplane which cuts into the base of the Blue Ridge. Near the Blue Ridge its surface is broken by monadnock groups such as Tallulah Mountains, but its degree of perfection increases notably toward the south. Around Clarkesville it is an almost perfect erosion surface at an elevation of approximately 1500 feet. A good impression of the topography in this locality may be gained by examining Plate LXV.

The Piedmont is the third part of this interesting area. Chattahoochee and Chattooga Ridges traverse the Walhalla, Georgia-North Carolina quadrangle, and separate the higher Chattahoochee level from the lower Piedmont level. These ridges are really two parts of a southeastward facing escarpment, broken by Tugaloo River. In this respect they are quite like the Blue Ridge. In fact, it is sometimes referred to as the Blue Ridge. The main Blue Ridge, however, lies to the northwest and marks the northern boundary of the Chattahoochee basin. The writer

suggests that the Chattooga-Chattahoochee Ridge be considered a branch of the Blue Ridge which leaves the main scarp in the southwestern corner of the Cowee quadrangle.

The surface of the Piedmont, like the higher level west of the escarpment, is a remarkable peneplane, as may be seen by referring to Plate LXVI. The photograph reproduced there shows the Piedmont as seen from the Chattahoochee escarpment near Toccoa, Georgia. In Plate LXII, we see the escarpment itself as viewed from the Piedmont.

Since it is now known that the Tallulah River formerly belonged to the Chattahoochee system, it will be noted that these three divisions were originally drained by three different stream groups. The northern area discharged through the Tennessee River to the Gulf of Mexico, the intermediate area directly to the Gulf, and the Piedmont to the Atlantic. The erosional history of the region has obviously been influenced by the differences in stream length among the members of these groups.

The Record of Harrisburg Erosion in the Chattahoochee Area

In the sections dealing with the Hiwassee and Little Tennessee basins, the Harrisburg erosion level was traced upstream to elevations of approximately 2100 feet. Since the Tallulah formerly entered the Chattahoochee River, it is proper to consider its basin as part of that of the Chattahoochee. An erosion level is remarkably well developed in the area centering around the junction of the Tallulah and Chattooga Rivers at an elevation of about 1500 feet. It is traced up the Chattooga River to approximately 1800 feet in the valley of West Fork in the northern part of the Walhalla map. It was also well developed in the basin of Tallulah River at elevations as high as 1850 feet, or perhaps 1900 feet in the tributary valley of Tiger Creek. The excellent intrenched meanders along Tallulah River above Tallulah Falls, were apparently cut in this surface. The accordant hills in the upper Tallulah Valley around Burton, on the Dahlonega map, have an elevation of at least 2000 feet. At this point it is interesting to note the striking linearity in trend of the several stream valleys east of Burton, including Timpson, Scott,

and War Woman Creeks. Persimmon Creek still farther upstream has an open basin well above 2000 feet in elevation. In fact, it is slightly higher than the Harrisburg floor of the Little Tennessee River two or three miles to the east beyond the low Keener Gap. In general, however, the peneplane stands at an elevation of 1500 feet throughout the upper portions of the Chattahoochee and Soque River basins, and it is only in the headwater portions of Chattooga and Tallulah Valleys that it rises appreciably higher. The upstream extensions are not more than several miles in width and in many places they are much narrower.

The Erosional History of the Chattahoochee Area

LaForge has outlined the erosional history of the Central Upland. He assigns the different levels to different erosion cycles, the highest representing the work of the oldest cycle and the lowest the most recent. His account includes four or five different erosion cycles, the oldest of which is represented at present in the surface of the Dahlonega Plateau. In order to make clear his point of view, a rather lengthy extract from his paper is introduced at this point.

"The general course of events in the carving of the surface of the Central Upland, as far as it has been made out by applying the principles of interpretation briefly outlined above, is as follows. At some past time, since the great movement of the earth's crust in the southern Appalachian region that resulted in the folding and squeezing of the rocks and the elevation of the surface to mountainous heights and relief, there was a long cycle of seemingly uninterrupted degradation of the surface of the region now including the Central Upland. This cycle may have been preceded by others of which there is no record preserved, but during it reduction of the surface proceeded so far that practically all the area of the Central Upland was reduced to a peneplain or generally base-leveled surface. This peneplain probably also extended over a considerable part of the area now the Appalachian Valley and part or all of that now covered by the Coastal Plain. Only a few monadnocks stood above the general

surface in the northern part, adjacent to the region that was still mountainous and that now forms the Highland. Remnants of this peneplain are preserved in the surface of the Dahlonega Plateau, which is clearly part of an old planated, or nearly base-leveled, surface.

"The formation of this peneplain was eventually terminated, as all such cycles are, by some sort of crustal movement. The area in which its remnants are now preserved was uplifted a few hundred feet and renewed degradation began the carving of a second peneplain, now preserved in the Gainesville platform of the Atlanta Plateau. Before this had been developed over so great an area as the older one another movement of the crust brought its formation to an end and inaugurated a new cycle, in which a third surface was developed, now represented by the Fairburn Platform of the Atlanta Plateau. Its formation was in turn interrupted and at least one, if not two, younger peneplains were subsequently developed over parts of the area now comprised in Midland Georgia. Each cycle seems to have been shorter than its predecessor, or else the rate of degradation became progressively slower, as each peneplain in turn was developed over a smaller area than the one preceding it. If this were not the case the older ones would have been completely removed by later degradation and no evidence of their existence would have been preserved in old base-leveled surfaces. In the later cycles, especially in the one during which the Washington Plateau was formed, the planation was almost complete throughout the area over which the surface was developed, for there are only one or two small monadnocks standing above its surface."

The present writer would like to suggest the possible correlation of the Chattahoochee level with that of the basin of the Little Tennessee, on the one hand, and with the Piedmont on the other.

The correlation of the Chattahoochee level with that of the Little Tennessee River would find support in map and field evidence. There is an unquestioned erosion level in the valleys and tributaries of the Chattooga and Tallulah Rivers which rises up to 1800 feet in the case of the former, and to elevations above 2000 feet in the case of the latter. These basins are as well

developed at these levels as are those of the Little Tennessee and other rivers in the upland. The writer lays little emphasis upon the actual elevation of these remnants of Harrisburg erosion when such remnants are separated by distance or marked by contrasts in rock resistance. On the other hand, when a group of competing streams separated by a low divide, as at Keener Gap, develop erosion surfaces in rocks of similar types, they might be expected to be near the same level. This, however, is not necessary. If there happens to be a rocky barrier in the valley of one stream and not in the other, or if there is a contrast in distance to the sea, they may stand at different levels. Nevertheless, for those to whom elevation means a great deal in the correlation of levels, this situation ought to have a strong appeal. In this section the Rabun Gap divide is intentionally left out of the discussion because the divide was apparently not in this position in Harrisburg time as will be indicated in a subsequent paragraph. The Blue Ridge at this point is really broken by a through-going valley. Thus it appears that while the general surface of the Chattahoochee peneplane has an elevation of 1500 feet, its upstream extensions rise to heights quite similar to those attained by the Harrisburg remnants in the basins of the upland.

The perfection of development attained by the Chattahoochee peneplane is comparable to that of the local peneplane of the Little Tennessee River valley. Around Clarkesville, Georgia, there are very few monadnocks and there is a broad expanse of erosion surface. Currahee Mountain to the east rises as a sharp monadnock above this level. Above Tallulah Falls and behind Tallulah Mountains, the erosion surface is very narrow and not uniform in width. Some of the tributary valleys farther upstream have broadly open Harrisburg Valleys, while others show few traces of this erosion record. In this respect the Chattahoochee basin is quite like the basins of the upland.

In the next place, the degree of dissection appears to be quite similar to that of the basins in the Older Appalachians. In the upstream remnants of this surface, if we may judge from the map, there is less dissection than in the territory downstream, as for example on the Dahlonega quadrangle. It is difficult to

make a comparison with the valley of the Chattooga River because of its steepened gradient due to piracy. The basin of Tiger Creek furnishes a better basis of comparison. At the heads of the valleys on both sides of the Blue Ridge divide, the streams are flowing near their Harrisburg level, and they become more and more intrenched downstream. Anyone who drives up and down these valleys must be impressed by the accordance of hills bordering the valley. While they rise in elevation upstream, they come nearer the floor of the present valley. The similarity between the features in the upper part of the basin of the Little Tennessee and those in the upper part of the Tallulah basin is striking.

The Chattahoochee and the Piedmont Compared

In suggesting the possible correlation of the Chattahoochee with the Piedmont the writer recognizes at the outset several difficulties. In the first place, they are separated in the Tallulah area by a marked escarpment 500 feet in height. In the next place, the depth of soil seems to be greater in the Piedmont than on the upper level. Finally, the upper level seems to be underlain in part at least by resistant rock such as quartzite.

The discrepancy in elevation between the two levels, amounting to 500 feet near Toccoa, is quite marked and would seem to indicate that these levels represent the work of two distinct cycles. As pointed out by Johnson, the escarpment becomes lower and lower toward the southwest, until in the latitude of Atlanta it virtually disappears, and the Chattahoochee and Piedmont levels coalesce at an altitude of approximately 1000 feet. In this locality it seems impossible to discriminate between the two levels on the basis of elevation or degree of dissection or any other basis. The two appear to be part of one and the same erosion level.

As to the depth of soil being greater in the Piedmont than on the upper level, the writer can record only his own observations. It did seem to him that there was a deeper decay in the Piedmont than in the Chattahoochee country where occasional outcrops of bedrock do appear in road cuts. In the Piedmont

solid rock seldom appears even in the deepest excavations along railroads and highways. Excess of soil depth does not seem to the writer to point definitely to either an earlier or a later date of formation.

The Harrisburg Peneplane is developed elsewhere only on rocks of moderate to inferior resistance. Quartzite occurs in the Tallulah Falls region where the peneplane is developed. The area of surface underlain by quartzite is not large and the region as a whole comprises a great variety of disordered crystalline rocks. Nevertheless, the occurrence of resistant rocks in an area peneplaned supposedly in the Harrisburg cycle raises a serious question in the mind of the writer as to the correctness of the date of origin.

When the present topography of the Piedmont and the upper level are compared, we find a striking similarity. The peneplane is almost equally well-developed in the two areas, and the degree of dissection is not essentially different. Typical views from the highways traversing the regions are essentially alike. If they be interpreted as products of two different cycles, the upper should probably be assigned to the Schooley and the lower unquestionably to the Harrisburg. This theory faces the difficulty of explaining how the upper peneplane could have stood through the Harrisburg cycle without having been seriously modified by it. So far as the writer was able to observe in a rather brief field study, there are no recognizable traces of the work of a second cycle on the Chattahoochee upland. The slopes apparently grade down uniformly to the present valleys. It is believed improbable that the peneplane endured Harrisburg erosion without showing the effects of it. Furthermore, even in the hard rock areas of the Appalachian Plateau and the Older Appalachians the Schooley exists today only on narrow divides which in rare situations have a high degree of accordance. So far as the writer is aware, the Schooley Peneplane is not preserved anywhere on broad inter-stream areas such as occur commonly in the Chattahoochee basin. Schooley Mountain in New Jersey, the type locality, is not characterized by flatness of surface.

Possible Explanation of Chattahoochee Level

It has already been pointed out that there are three widely different drainage systems in this area. The upland is drained by streams which cross rocky barriers and reach the sea after flowing a great distance. The heads of streams on the Chattahoochee level have developed relatively high-lying basins, which rise several hundred feet above the general Chattahoochee level. These streams flow directly to the Gulf. The streams of the Piedmont have neither rocky barriers nor a great distance to the sea. It seems to the writer that great distance to the sea and rocky barriers may explain the nature and the elevation of the high-lying basins in the upland. The Chattahoochee level at an intermediate elevation was developed by streams of intermediate length, while the Piedmont was carved by short streams. In the area around Atlanta where the distances to the Gulf and the Atlantic are approximately the same, there is no appreciable difference between the elevation of the Chattahoochee and Piedmont levels.

The greater extent of peneplane development south and east of the Blue Ridge may have been due to the slight difference in altitude between the Schooley and Harrisburg levels in this area. If the Schooley peneplane was uplifted but slightly in the Piedmont and Chattahoochee areas, and if the major streams have maintained their present courses since that cycle, the Harrisburg Peneplane may have been developed in these areas only a few hundred feet at most below the Schooley level. Hayes and Campbell (34) thought that the Upland Peneplane was not uplifted greatly in the Atlanta district as shown in the following quotation.

"In the region southwest from Atlanta as far as the Coosa River, the present attitude of the [Cretaceous] peneplain differs from that in any other portion of the province. In this region the baseleveled plain has suffered but little uplift from the position in which it was formed, and this slight elevation has taken place in very recent geologic time. Hence the peneplain is well preserved and many of the present streams, as the Tallapoosa and

its tributaries, are flowing partly on this old surface and partly in channels which they have been able to sink but a short distance below it, although it now stands from 1,000 to 1,400 feet above sealevel. In northern Georgia it merges into the Smoky mountain type, differing from the latter in the greater perfection to which the baseleveling process was carried and in the more perfect preservation from subsequent erosion. This peneplain is well preserved in Dug Down mountain, south of Rockmart, Georgia, and it is from this plain that the historic knobs of Kennesaw and Stone mountain stand up so prominently."

While it is doubtful whether the Schooley Peneplane has remained for so long a time with as little dissection as indicated above, it is possible that its surface may have been lowered only slightly during subsequent time, and largely by the removal of the deep soil mantle.

The Harrisburg Levels near Blue Ridge, Georgia

There is a pronounced break in the Blue Ridge scarp along the line between Blue Ridge and Ellijay, Georgia. West of this locality the name Blue Ridge does not appear on the map but the mountain which corresponds to it rises to an elevation of 3600 feet in Flat Top Mountain and joins Cohutta Mountain a few miles farther west. This break in the Blue Ridge was caused by erosion along a weak rock belt which Keith has described as the Murphy Marble. The divide between the Toccoa River on the north and the Ellijay on the south is not at the constriction on the Fannin-Gilmer County line as one would expect, but at the town of Blue Ridge some three miles to the northeast. A change in the drainage at this point has occurred since the completion of the Harrisburg cycle. It will be briefly described in a subsequent paragraph.

At present we are concerned merely with the levels on the two sides of the divide. The widely developed erosion level in the vicinity of Ellijay has an elevation of about 1600 feet. It slopes down the Coosawattee River to 1500 feet where the stream leaves the crystallines and enters the Appalachian Valley. The same surface rises upstream from Ellijay along the course of

Ellijay River and Cherrylog Creek to an altitude of 1800 to 1900 feet near the county line. On the Toccoa side the erosion level attains a height of approximately 2000 feet. Thus there are on opposite sides of a low divide, erosion levels developed by streams in a former cycle which stand not more than 200 feet apart. The general level of the Toccoa basin is higher than that of the Ellijay, but the former, although a larger stream, crosses a rocky barrier in its lower course. In the Ellijay basin the upper part of the stream is more deeply intrenched below its former level than on the Toccoa side due to piracy, but otherwise the present topography is quite similar. LaForge, in describing the Dahlonega Plateau says, "It is continuous through the gap at Blue Ridge with the Ducktown Plateau of the Highland province."

Summary of Relations between Piedmont and other Erosion Levels

In the Roanoke, Catawba, Tallulah, and Ellijay-Blue Ridge localities we have studied the erosion surface developed on crystallines, commonly called the Piedmont Peneplane, and described its relation to the peneplanes on the northwest. We have noted that the erosion surface in every case rises upstream. It has also been shown that there are local peneplane levels in adjacent basins, presumably of Harrisburg age, which have a discrepancy in elevation, as much as 500 or 600 feet in some places, while in others they are practically accordant. These illustrations indicate that elevation is not a reliable criterion to be used in correlating erosion levels.

The correlation of all of these local levels with the more extensive peneplane in the Appalachian Valley and with the Piedmont Peneplane, is based first upon a genetic relationship as indicated in such cases as the New River where the record of Harrisburg erosion can be traced upstream from an elevation of about 2000 feet to more than 3500 feet. It is believed that this is unmistakable evidence of unity in the regional history in a period not far removed in time. The second line of evidence, in support of this proposed correlation, is found in the striking

similarity of the topographic forms wherever this erosion surface was developed, bearing in mind the lesser degree of dissection in the upstream parts of the basins. Some significance is also attached to the presence of intrenched meanders, uniform in character, in many different drainage basins.

HARRISBURG EROSION IN THE APPALACHIAN PLATEAU

In the course of field studies in the Southern Appalachians the writer has had occasion to traverse many miles in the Plateau between the Potomac River and Chattanooga, Tennessee. Observations made along these routes strongly indicate that the Schooley Peneplane is preserved less extensively than the Harrisburg on the present surface of the Plateau. A belt of country along the Allegheny Front varying in width from a few miles up to perhaps fifty or seventy-five miles is the area in which the Schooley is preserved. A few ridges west of this belt maintain this level at lower elevations. Resistant sandstones and conglomerates, almost horizontal in position, uphold the Schooley Peneplane. It is possible that in some localities they were never brought down to the peneplane level. While it is known that the erosion surface bevels the structure at a low angle, it is possible that local flat surfaces which have sometimes been regarded as peneplane remnants may be structural in origin.

During the Harrisburg cycle a peneplane was developed over the central and western parts of the Plateau, the remnants of which form the Plateau surface at the present time. Furthermore, as already explained in connection with the New River basin the Harrisburg Peneplane forms the surface over a considerable area of soft rocks just west of the scarp in the heart of the Schooley Upland. The Harrisburg is found in other high-lying situations in West Virginia as well as in lowlands such as the Valley River.

In Kentucky the Schooley is preserved in a narrow belt called the Coal Basin for a short distance northwest of Cumberland Mountain. A fairly pronounced scarp separates it from the lower Highland Rim which has an elevation of 1400 feet. Another escarpment marks the boundary between the Highland

Rim and the Lexington Plain. The Blue Grass Region, or the Lexington Plain, with an altitude of 1000 feet, is underlain by limestone while the Highland Rim is formed for the most part on sandstone and shale. Pronounced accordancy of hilltop is characteristic alike of the Lexington Plain and the Highland Rim. The accordance is less marked in the Schooley area to the east. The surfaces of these three areas represent uplifted and dissected peneplanes. There is general agreement in regarding the highest level, that is, the one preserved in the Coal Basin, as the equivalent of the Schooley. As to the correlation of the two lower levels there is difference of opinion. Bowman (3) assigns the Lexington and Highland Rim Peneplanes to different cycles. Campbell (12) refers the Highland Rim to the Cretaceous or Schooley. Others correlate the Highland Rim with the Lexington Plain and assign both to the Harrisburg cycle. The writer favors the last view which accords with the interpretation of similar relationships in and around the Older Appalachians.

The Middlesboro, Kentucky-Tennessee-Virginia, topographic map which covers the Cumberland Gap area is instructive in this connection. The Powell River basin southeast of Cumberland Mountain preserves the Harrisburg Peneplane over a large area at an elevation of 1600 to 1750 feet. The magnificent meanders of Powell River were intrenched in a floodplain, the remnants of which now stand about 1500 feet above sea level. North of Cumberland Mountain a broadly open basin with an area of seven or eight square miles centers around Middlesboro, Kentucky. Yellow Creek drains this basin and discharges into Cumberland River. The present altitude of the basin around Middlesboro is, approximately, 1250 feet, which is almost as low as the remnants of Harrisburg erosion along the Cumberland River in the northern part of the Cumberland Gap quadrangle. Its flatness indicates extremely low rock resistance and its present level may not be the Harrisburg surface at all. The same erosion level which is widely developed in the northwestern half of the Williamsburg quadrangle obviously continues as a narrow strip up the Cumberland River well into the area where the Schooley

is maintained by the present surface of the Plateau. If these field observations are correctly interpreted, the writer can see no reason why the lower surface should not be correlated with the known Harrisburg on the southeast side of Cumberland Mountain.

The unique "Powell Valley," a narrow lowland adjacent to the Cumberland Mountain-Powell Mountain ridge on the southeast, has an elevation of about 1300 feet, or approximately three hundred feet below the Harrisburg Peneplane. Where it is most typically developed it has no longitudinal stream, all the drainage being carried off by short transverse streams. It may represent an abandoned valley, but more likely it has been reduced by solution. Depression contours indicate that much of the drainage goes off through underground channels.

Emory River drains an area of the Cumberland Plateau in the Wartburg, Tennessee, quadrangle. The topography of much of this basin certainly resembles the Harrisburg. As one follows down this stream to the Appalachian Valley, it seems that this level descends to unite with the general level of the Valley. This correlation is quite tentative and may be found on further study to be incorrect.

A second possible line of evidence in support of the correlation of the Lexington and Highland Rim Peneplanes is found in the intrenched meanders of master streams. Reference has already been made to the Cumberland River. Kentucky River shows the same features. In the Richmond area of the Lexington Plain the meander spurs preserve the old floodplain at an elevation of 800 to 900 feet, while in the Highland Rim to the east the meander spurs have an elevation of 1000 feet. The meander spurs in the Lexington Plain are 100 to 200 feet below the Peneplane level while in the Highland Rim the spurs are about 300 feet below the level of the Peneplane. This would seem to be normal in view of the contrast in rock resistance.

In the third place, the difference in level between the Lexington Plain and the Highland Rim may be due primarily to differences in rock resistance and rock types. The limestone area was doubtless reduced lower than the Highland Rim during Harris-

burg time, because of lower resistance and also because it is downstream from the Rim. Since the uplift which closed the cycle the Lexington Plain has been lowered, chiefly by solution, more rapidly than the higher area to the east. Matson (62) has pointed out the extent of underground circulation in the following lines:

"The flat-topped remnants of the peneplain in Woodford, Franklin, and Fayette Counties have the largest underground systems of drainage and supply the most copious springs of the region. Unfortunately, few of these caverns are accessible, and their size and the extent of their ramifications can be inferred only by the size of the springs and the number and size of the sink holes. On these flat-topped divides there is practically no surface drainage, and the topography is marked by a series of sink holes which receive a large part of the rainfall."

During a recent visit to the Highland Rim area of Kentucky the writer was impressed by the fact that the Highland Rim Peneplane slopes down toward the east, which is upstream. This direction of descent is not normal, and in view of the eastward dip of the beds suggests structural control. Along the margin of the Rim east of Richmond, Kentucky, the elevation of the present surface is 1300 to 1400 feet, while 15 miles to the east, around Beattyville, there are extensive interstream areas at 1200 feet in altitude. At the close of Harrisburg time it is quite possible that the western part of the Rim was a low cuesta-like monadnock ridge.

In addition to the large areas of Harrisburg surface in the Appalachian Plateau this peneplane is broadly developed in an area around Lewisburg, West Virginia, in the drainage basin of Greenbrier River.

POST-HARRISBURG EROSION

As we take up the study of the nature and extent of erosion since the uplift which terminated the Harrisburg cycle, we must bear in mind that the impulse of uplift and its consequent quickening of the erosive processes was not felt in the crystalline area of the Older Appalachians until long after the rejuvenated streams

had begun their work in the Appalachian Valley. Because of this fact, the Harrisburg areas in this province are very much less dissected than those in the Valley to the west. The writer has seen no evidence to indicate that more than one cycle is required to account for the features produced since the uplift of the Harrisburg Peneplane. There are few stream terraces, and the floodplains themselves are for the most part narrow and bordered by steep valley walls. A typical view of the French Broad River may be seen in Plate LXVII and the New River in Plate LXVIII. The streams are young to early mature, except in their upper courses where the rejuvenation has not yet been felt. They have inherited the meanders of Harrisburg time and intrenched themselves to depths of several hundred feet, and in a few instances even more. These meanders are similar in form, but not usually as wide as those found along streams in the Valley and in the Blue Grass region of Kentucky. The relief in the basins varies from 50 feet or less near the heads of the streams to 300 to 400 feet downstream. Where piracy has occurred since Harrisburg time, as, for instance, in the Green and North Pacolet valleys on the Saluda quadrangle, the dissection of the peneplane has gone much farther than in other localities. No flat interstream areas remain here and the relief, in places, is more than 500 feet.

No special study has been made of the record of erosion in post-Harrisburg time in the Appalachian Valley. As pointed out by Hayes, the limestone rocks there have been extensively eroded, so much, in fact, that a peneplane lower than the Harrisburg was believed to have been produced. The writer has observed localities in this region where there seems to be a level 100 to 200 feet below the general upland level of the valley floor. Such a level occurs only on extremely weak rocks and is particularly apt to be found along larger streams, especially near their junctions. There are also unquestioned stream terraces in widely separated localities.

It seems to the writer that, in the interpretation of the later erosional history of the Appalachian Valley, due account must be taken of the relatively rapid weathering of limestone by solu-

tion. This idea has been discussed by Ward.[5] The interstream areas, which are expected to preserve longest the surface of a former peneplane, have been lowered appreciably, perhaps several hundred feet since Harrisburg time, chiefly by solution. A limestone area may be reduced considerably more rapidly than an area of crystallines, and preserve at the same time a fair accordance of hilltop. It is conceivable that in a limestone area where solution effects are at a maximum, the hilltops may be lowered almost as rapidly as the stream lowers its gradient, at least in the later stage of the stream cycle when its gradient is relatively low. Within the Great Valley itself there are considerable variations in the resistance of the rock. Some of the sandy shales and cherty limestones are fairly hard, while the purer limestones and shales are often extremely weak.

The later erosional history of the Piedmont seems to be quite similar to that of the Older Appalachians. In general, however, the streams are more advanced in the present cycle, and we find many examples of broad floodplains. There are also moderately intrenched meanders, and the same accordance of hilltop that occurs in the Older Appalachians. The depth of dissection is less than that in the downstream parts of the Harrisburg areas in the mountains.

In spite of dissection since its formation, Harrisburg remnants are characteristically alike in the Piedmont and in the Older Appalachians, as well as in the intermontane valleys of the Newer Appalachians. It is only in some parts of the Appalachain Valley where, due to low resistance, the later dissection has been extensive that we find any notable exception to the general similarity among these remnants.

[5] Ward, Freeman. The Role of Solution in Peneplanation. J. G. 38: 262-270 (1930).

The Origin of the Blue Ridge

The escarpment of the Blue Ridge, which rises from 1000 to 1500 feet above the Piedmont on the east, has been a problem to geologists ever since the principles of geomorphology have been applied to the Southern Appalachians. When these studies were begun in 1923, the main object was to discover which of the theories of origin previously proposed best explained the facts. To this end almost all of the highways which cross the scarp between Roanoke, Virginia and the Cohutta Mountains in northwestern Georgia were traversed one or more times. After a fairly careful study of the field evidence the fault or fault-line theory of origin was considered (80) and found to have little if any application. It seemed then that the only satisfactory approach to the solution of the problem lay in the erosional history of the two provinces which the scarp separates. This method was undertaken and study was made along three lines, topographic maps, additional field work, and projected profiles covering all of the area south of Roanoke.

It has been thought that the Piedmont surface might have been carved by the waves of the sea which supposedly rolled as far inland as the Blue Ridge scarp. This would make the scarp a sea cliff. Although it is not proposed here to go exhaustively into a consideration of a possible marine origin of the Piedmont and Blue Ridge, it seems desirable to record several observations which seem to refute this theory, and to indicate the wisdom of turning in other directions for a correct solution of the problem. The absence of all traces of recent marine deposits on the present surface of the Piedmont is difficult to reconcile with the idea of a late occupancy of this region by the sea. It is hard to conceive how every bit of marine deposit could have been swept away by subsequent erosion, while the region as a whole has been only moderately dissected since the time of peneplanation. The profiles have not revealed any marine terraces in the Piedmont but perhaps the vertical exaggeration was not sufficient to bring them out even if they actually do exist.

A considerable number of typical Piedmont monadnocks were

examined with reference to the relative steepness of their northwestern and southeastern slopes. Obviously, if they are residual erosion features left standing above a marine peneplane, they should in general have steeper slopes on the side toward the open sea. The influence of rock structure, however, must not be overlooked in this connection. An occasional monadnock was found to have a steeper southeastern slope, but more were steeper on the northwest.

A third difficulty in the way of a marine interpretation is the broad development of the Piedmont Peneplane behind long linear monadnocks lying close to the Blue Ridge. South Mountains and Brushy Mountain in western North Carolina are among the best examples of this type of feature. In both cases the Piedmont is magnificently developed between the monadnock and the Blue Ridge. The peneplane behind the massive South Mountains is developed as a prong for at least thirty miles. It rises gradually up the Catawba River from Morganton to Marion, and on to Old Fort. In fact the mature valley formed in the same cycle continues for some miles beyond the last-mentioned point. It seems wholly improbable that the waves of the sea could work so effectively behind such a barrier and especially to develop the surface which steepens appreciably up the Catawba River. It might be argued that the upper course of the Catawba was graded when it reached the sea, the shoreline of which was near the base of the scarp. This does not seem probable because the hills preserving this level rise upstream without any break in slope and there does not appear to be any possible combination of fluviatile and marine features. In addition to these two large extensions of Piedmont surface behind monadnocks, we find scores of other examples on a smaller scale. Near Afton, Virginia, west of Charlottesville, there is an open basin behind a group of monadnocks which unquestionably represents an upstream extension of the Mechum River lowland, and which correlates, therefore, with the Piedmont.

If we must then turn from the fault theory of origin of the Blue Ridge and also from the marine theory, it seems that we must look to the normal erosional history for a solution. The

only factor in addition to stream erosion that requires consideration is differential uplift or warping. Campbell, in addresses before the Geological Society of Washington (7) and the Geological Society of America (9), as well as in other papers, has laid emphasis upon warping. The same idea was elaborated upon in a paper by Hayes and Campbell entitled "Geomorphology of the Southern Appalachians." The following extract from the second address referred to above will help the reader to understand the rôle of warping as set forth by Campbell:

"The production of a scarp from a monoclinal fold is perhaps the most remarkable form, and it is due to a peculiar combination of slow, regular uplift, homogeneous rocks, and baseleveling conditions outside of the area affected by the uplift. This principle is applied to the solution of the Blue Ridge scarp in North Carolina, and it is shown that the physical features of that region could have been produced by a monoclinal uplift in a broad peneplain. On this supposition the Blue Ridge plateau was once continuous with the Piedmont plain, but the latter remained at sea level while the former was slowly elevated 2000 feet. There were halts in this movement, during which partial peneplains were formed on the western side of the Blue Ridge. The final result of such a combination of crustal movements and periods of baseleveling is that all of the peneplains on the western side of the Blue Ridge, collectively, represent approximately the same time interval as that represented on the eastern side by the Piedmont plain. This theory also explains the present condition of the New River-Roanoke divide, and why the former stream has not been captured by the latter—a crucial test for all theories relating to the origin of this scarp."

The evidence for and against this theory was reviewed in an earlier paper (81). It is safe to say that the downstream slope of the Harrisburg surfaces is largely original. On the other hand it is quite unlikely that large areas are uplifted uniformly. The methods used by the present writer are not yet sufficiently refined to bring out the exact amount of warping of the different peneplanes. We are still at a loss to know the extent of warping of the Upland or Schooley Peneplane. It was developed over

some resistant rock areas where the general level was never as low as in adjacent weak rock areas. In other words, it was not a perfect peneplane. This is especially true in the Older Appalachians where rock resistances varied enormously. Furthermore, the Schooley surface has been so much dissected in the Harrisburg and in the present cycle that its restoration is difficult. The Schooley obviously existed where the Harrisburg now exists, but there is no way of knowing the depth of dissection accomplished in the Harrisburg cycle except by comparing the elevation of the remnants of the Harrisburg with the elevation of the present remnants of the Schooley. These comparisons have revealed, as shown in previous pages, considerable variations.

So far as the writer is aware, there have been no important reversals in direction of flow of the major drainage lines in the Older Appalachians of the South since Schooley time. Some streams have effected piracies, especially along the Blue Ridge, since the close of the Harrisburg cycle. There is nothing in the geological history which would indicate any change in the general direction of drainage except in the piracy cases above referred to, and in the Appalachian Valley where subsequent drainage has supplanted the crosswise drainage of earlier time. If this is true it is fair to assume that the Blue Ridge was during Schooley time the divide between the Atlantic and Gulf drainage. That is to say, the Blue Ridge may well have marked this important divide as far back in the erosional record as we can go at the present time. At that early date, however, it was a divide with equal or subequal slopes, and not an escarpment as at present. Its height and scarp form have developed as a result of erosional processes operating during and following Schooley time. Obviously, it is not intended to suggest here that the position of the Blue Ridge has remained the same, for, as pointed out by Davis, it is steadily retreating toward the northwest. It is impossible to say how far the divide has shifted westward since early in the Schooley cycle. The tributaries which drained it were small ones associated with the heads of the streams, and it is possible that its migration has not been so rapid. It would depend also upon the nature of the surface upon which the Schooley

streams worked. If there was a mountainous tract along the divide at the beginning of the Schooley cycle, the Atlantic streams may have gnawed vigorously into the divide even early in the cycle. If, on the other hand, the divide was broad and flat, the headward cutting of these streams would not have been vigorous enough to have caused great retreat until the cycle was well advanced.

In this connection it is interesting to note that the pattern of the streams on the Piedmont near the base of the Blue Ridge does not indicate that much territory was abstracted from the Gulf drainage during the Schooley cycle. The branches of these streams are for the most part dendritic in pattern and quite normal for streams draining a divide. The courses of the Catawba and Yadkin Rivers, which parallel the scarp and drain lowlands on weak rock behind South and Brushy Mountains respectively, might be thought of as having taken their upper courses from the higher level. It is more probable, however, that they have had their positions determined by weak rock. Although there are other traces of stream courses along the western margin of the Piedmont which indicate a possible inheritance from the Upland level, it seems that such evidence is scanty.

If a stream the size of the South Fork of New River, which is at present in danger of capture by the Middle Fork of Reddies River as suggested by Davis, should have been diverted in Schooley time from the Gulf to the Atlantic drainage, some indication of this fact should be found in the present drainage pattern. Apparently the divide did not retreat far enough in that cycle to reach the valleys of larger streams. Furthermore, on the present interpretation the divide did not have its strongly contrasted slopes and its consequent scarp form until toward the close of the Schooley cycle. Under such circumstances large drainage basins would not have been transferred bodily by piracy from the western to the eastern slope. Perhaps then the Blue Ridge has not retreated many miles from its position in Schooley time.

If the major divide in Schooley time was approximately where it is today, although a shift of twenty or more miles would not invalidate this tentative theory, then the Schooley Peneplane

must have been developed by shorter Atlantic streams in the Piedmont country and longer Gulf streams in the upland. In regard to this point, Davis (27) says, ". . . . it seems manifest that neighboring peneplains eroded by river systems of different length, must stand at unequal height along their line of contact; that a relatively well-defined escarpment must separate the two plains; and that active retrogressive erosion must take place on the escarpment." As an additional factor, the same author points out that "The occurrence of resistant rocky barriers on the course of the longer river system would certainly conspire with excess of length to maintain the headwater basins at a higher level than those of neighboring shorter river systems, on whose course fewer hard-rock barriers might be expected; and in the case in hand, there is good reason for thinking that this additional cause is operative." The present writer would add that even in the long Schooley cycle rock resistance was unquestionably a factor in determining the elevation and perfection of the peneplane and the number and prominence of the monadnocks. There are so many bold outcrops of massive rock in the upland of the Older Appalachians and so many fewer in the Piedmont, that some value is to be attached to this difference.

At the close of the Schooley cycle the peneplane stood perhaps several hundred feet higher in the upland than in the Piedmont and the two levels broke joint along the Blue Ridge divide. It was late in the Schooley cycle when the peneplanes were approaching completion that the Blue Ridge first took on its modern character. When the Schooley Peneplane was uplifted one of the main axes of uplift according to Hayes and Campbell was along the Blue Ridge. This accentuated the disparity between the upper and lower levels. During the Harrisburg cycle which followed, the streams in the upland developed local peneplanes and mature valleys in the softer rock belts, and destroyed all the flat Schooley surfaces, so that narrow divides only were left. The massive monadnocks were but slightly affected. In the Piedmont the streams operated upon a low-lying peneplane and reworked it to a lower general level. It is quite possible that this dissection did not go much deeper than the depth of decay on the

Schooley surface. The same would apply also to the Chattahoochee level.

The scarp was driven back during this cycle, but the streams were small and the rocks hard, and consequently the rate of retreat may have been slow. An impressive showing could not be made until some of the upland streams were captured.

The uplift which closed the Harrisburg cycle and inaugurated the present was likewise greatest along the Blue Ridge. This differential movement gave the Blue Ridge its present height, and accelerated erosion along the scarp. These streams have succeeded in many localities in abstracting drainage territory from the leisurely flowing streams on the upland.

OBJECTIONS TO THE PRESENT INTERPRETATION

The great perfection and extent of the Piedmont Peneplane as compared with the local peneplanes in the upland. This may be accounted for by a combination of factors including; (1) shorter distance to the sea, (2) absence of rocky barriers, (3) weaker rocks, (4) relatively small amount of work required in the Harrisburg cycle to produce in the Piedmont an almost perfect peneplane. Furthermore the Piedmont is not everywhere such a perfect surface. Attention has already been called to the massive monadnocks of South and Brushy Mountains, which rise more than a thousand feet above the Piedmont. Associated with them are numerous small outliers. These and other monadnocks bear testimony to the statement that where hard rock occurs in the Piedmont it has topographic expression. The rocks of the Piedmont are dominantly of intermediate or low resistance while those in the upland are chiefly resistant, and only the Harrisburg basins represent areas of weak rock. The Blue Ridge north of Roanoke is essentially a hard rock feature; where the rock formations are resistant and massive the mountain forms are imposing, and where narrower and less resistant, they are subdued. A rock formation which appears on the geological map as a unit, may have in different localities quite different topographic expressions.

The Piedmont should be correlated with the Upland Peneplane on

the basis of perfection. The Upland Peneplane is preserved only along narrow divides because it has been extensively dissected. In large areas it has been entirely destroyed and a new lower peneplane formed. In the Piedmont, on the other hand, the peneplane is preserved on broad moderately dissected interstream areas of striking accordance. Furthermore, there is no trace in the Piedmont of two extensive erosion levels in the same district.

SUMMARY OF ORIGIN

In the tentative outline of the history of the Blue Ridge given above, the writer has emphasized the early location of the Atlantic-Gulf divide somewhere near the present Blue Ridge. Following this, the Blue Ridge scarp owes its existence to the fact that two peneplane surfaces at different levels "break joint" along this line. It is not the disparity between two peneplanes of the same age, except in those localities where the crest of the scarp is Harrisburg, but for the most part it is the break between an older Upland Peneplane and a younger lowland peneplane. Finally rock resistance is believed to have had an important rôle in preserving the scarp and causing it to stand out so conspicuously above the lower Piedmont, developed on somewhat weaker rocks.

Drainage Problems

We have already seen how local and regional peneplanes were developed at different elevations during the Harrisburg cycle. With the uplift of the region at the beginning of the present cycle, ideal conditions for stream piracy were brought about along the margins of these basins. In some instances two adjacent local peneplanes in the upland were separated by a scarp hundreds of feet in height. Such scarps were formed where the levels "broke joint." With rejuvenation through uplift the streams on the lower level gnawed vigorously back into the basins of streams on the upper level. As a result stream diversions were caused in different parts of the province, and especially along the Blue Ridge where the maximum discrepancy in level existed. Professor Davis (27) explained the process as it operates along this scarp. Because of its great importance in this, as well as in other provinces, it is in order to quote somewhat at length from his paper. In this extract, the author traces the future course of events in the case of Bee Rock Creek, an aggressive eastward flowing stream, as it undermines Crabtree Creek. It also shows that the Blue Ridge is a retreating escarpment.

"One of the western headwaters, Crabtree Creek, a branch of Toe River, is especially worth watching from the top of Mt. Mitchell, as an example of many others. It is in imminent danger of a flanking attack from a stealthy rival, whose underhand designs have been unwittingly masked beneath the innocent name of Bee Rock Creek. Boring Grub were a better name, for it is gnawing into the stem of the Crabtree, whose upper part will before long be cut off and go falling over to the eastern drainage system. This is all so plain, and the stealthy work is so clearly visible from the commanding point of view, that one is tempted to stay on top of the mountain and watch the progress of the piracy; but as it will continue in progress for some hundred thousand years, one has to come away reluctantly without waiting for the finish. But a foregone conclusion like this need not be waited for after all. The result is plainly inevitable, and its events can be foreseen. At the head of Bee Rock ravine, the

escarpment is within about an eighth of a mile from Crabtree, and Bee Rock Creek descends 1,500 feet in two miles from its source. As the escarpment is further gnawed away and pushed westward closer and closer to the Crabtree stem, more and more of the upland waters will make their way through the ground to reappear in the springs of the Bee Rock ravine. With this loss of volume by the Crabtree, its valley will be deepened more and more slowly: with the corresponding gain by the Bee Rock headsprings, its ravine will be gnawed back faster and faster into the Crabtree uplands. A time must come when one of the ravines will be pushed back into the very valley of the Crabtree, all of whose upper waters will then turn with their wash of the land to an eastward discharge at the "elbow of capture;" while the trimmed Crabtree trunk will carry only a diminished volume of water and a lessened tribute of rock waste to Toe River, and thence by the Nolichucky, French Broad, and Tennessee, to the Mississippi and the Gulf."

Professor Johnson in his paper on "Drainage Modifications in the Tallulah District" has clearly demonstrated that the Atlantic streams have abstracted drainage territory from the Gulf streams. It was a contest here between one stream flowing on the Piedmont or Tugaloo level and another stream on the upper or Chattahoochee level. The two are separated by the Chattahoochee escarpment, which has a height in this locality of 500 feet. This author goes very carefully into the field evidence and concludes "that the Chattooga formerly flowed southwest by way of Deep Creek, Soque River, and the Chattahoochee into the Gulf of Mexico, but was captured by the Tugaloo at a point below the junction of the Chattooga and the Tallulah, so that the waters of both these streams were diverted to the Atlantic drainage by way of the Savannah River. . . . . The cause of the capture was probably the advantage of a shorter course to the sea which the Savannah enjoyed, and by virtue of which it was able to reduce even its headwaters to a lower level than the upper Chattahoochee, and so to undermine and capture the latter."

Within limits, it has been possible to trace the former stream courses through a study of the Harrisburg basins. Where two

basins come together at different levels and a part of the higher basin at present drains into the lower basin, there is a strong suggestion that piracy has occurred since the uplift at the close of the Harrisburg cycle. This evidence is especially significant when the slope of the Harrisburg surface is out of keeping with the present stream direction, but normal for the stream direction in the higher basin.

In the following pages, some of the more important drainage changes noted in the Older Appalachians will be described. Mention has already been made of the piracy near Asheville where Hominy Creek has shorn the Pigeon River of some of its tributaries. This excellent example of drainage change has been treated in another paper (82). It involved two Harrisburg levels, adjacent to each other, but differing in elevation about 400 feet. The area lies in the heart of the Older Appalachians many miles west of the Blue Ridge scarp.

Attention has also been called to the abstracting of the upper Nantahala River by a tributary of the Little Tennessee. This diversion appears on the Nantahala, North Carolina-Tennessee, quadrangle. Keith (60) pointed out a capture on Amicalola Mountain southeast of Ellijay, Georgia, "where a stream flows with a gentle grade for 2 miles, and pitches abruptly down the moutain for five hundred feet and forms Amicalola Falls, the most picturesque in the Blue Ridge."

In the following descriptions of drainage changes, we will begin at the southern end of the Older Appalachians and proceed along the southern and eastern margins of the province until we complete the account at Roanoke, Virginia. It is not intended to be complete, but rather to indicate the number and variety of changes that have taken place, and cite the evidence.

THE TOCCOA BASIN

The town of Blue Ridge is situated in the Ocoee basin in the northwestern part of Georgia just a few miles south of the Tennessee line. The irregular Blue Ridge lies south and southeast of this locality, and a deep notch has been cut in it along the line running southwest from Blue Ridge to Ellijay. This conspicuous

break in the Blue Ridge is due to the presence in that locality of the Murphy Marble and other weak rocks, along a fault zone. The stream divide does not continue in a regular course across this belt, but makes a loop to the northeast passing through the village of Blue Ridge. Keith (60) says, "the headwater erosion of Ellijay River has pushed the divide northeastward until it is hardly more than two miles of the channel of the Toccoa."

This narrow indentation in the Toccoa Basin was caused by the headward growth of Cherrylog Creek, a tributary of Ellijay River, eating back into the slightly higher level of the Toccoa basin along a weak rock belt.

The fact that the divide here swings far away from its normal trend suggests that piracy has taken place. A brief field examination of the divide at Blue Ridge brought out several additional lines of evidence. There is in the village of Blue Ridge a normal transverse valley profile across the divide, indicating the presence of a former stream. A cover of several feet of soil, containing abundant quartz and other resistant gravels resting upon a weak schist, is exposed in the railroad cut on the divide. A stream-worn boulder with pitted surfaces was found imbedded in the soil, and other rounded boulders and gravels were found on the surface nearby. The number was not large but their position on the divide is significant. Cherrylog Creek is intrenched more deeply below the Harrisburg level north of the Fannin-Gilmer county line than to the south. The elevation of the Harrisburg level in the Toccoa basin is from 100 to 200 feet higher than in the Ellijay basin, and the upper Cherrylog Creek which now drains part of the former Toccoa basin flows in a narrow valley below this higher level. Finally, there is a slight constriction along the county line which indicates the probable position of the divide in Harrisburg time.

THE TALLULAH REGION

The capture of Chattooga River by the Tugaloo is carefully outlined in the essay by Professor Johnson referred to above. By this change Deep Creek, a member of the Chattahoochee

system lost a large portion of its drainage basin. The Tallulah piracy has unquestionably taken place since the formation of the Chattahoochee peneplane. If this surface is Harrisburg in age, then the piracy probably occurred soon after the uplift which terminated that cycle. This date would satisfy Professor Johnson's requirement that it was a "remote" change.

A very low divide stands between the upper Tallulah and upper Soque Rivers at the northwestern end of the Tallulah Mountains near the eastern margin of the Dahlonega quadrangle. The Tallulah River above this point flows in a southerly direction by the village of Burton, where a large dam has been constructed for power purposes. About three miles south of Burton, the river swings to the southeast, along the northern base of the Tallulah Mountains. The low divide is precisely in line with the upper course of the stream and also with the course of a tributary of Soque River. The writer visited this locality in June, 1930, and studied the divide and the topography to the north and south.

The northwestward extension of the Tallulah Mountains forms the present divide between the Tallulah and Soque Rivers, and it is followed by the Rabun-Habersham County line. The bend in the Tallulah River above this gap and the broad flat valley head of an unnamed tributary of Soque River south of the divide suggest at least the likelihood of a former connection between these drainage basins across the divide. The extensive development of Harrisburg topography in the upper part of the tributary of the Soque is hardly in keeping with the small volume of the stream. Evidence on the divide includes a large number of boulders, a few of which are rounded, and the flat character of the divide itself. The cross profile furthermore, is quite like that of a stream valley. The divide has an elevation between 1900 and 2000 feet and the accordant hills of the upper Tallulah rise 100 to 200 feet higher. In the direction of the Soque River the level descends. This gradual upstream rise of the Harrisburg surface through the upper part of the Soque, across the divide, and on up the Tallulah River valley offers a strong suggestion as to the former course of the upper Tallulah River.

The writer was unable to examine the valley of Tallulah River

below the supposed capture where additional data can doubtless be secured. The observed evidence, while not conclusive, indicates that the Tallulah formerly flowed across the divide south of Burton to join the Soque River. It is possible that this piracy was a result of the steepening of the gradient of the Tallulah River due to the capture of the Chattooga below Tallulah Falls.

It has already been pointed out that the low Rabun Gap which separates the waters of Stekoa Creek on the south from Little Tennessee River on the north was established in relatively recent time. Stekoa Creek, flowing by Clayton, empties into the Chattooga, a stream which has itself been captured farther down. Keith described this locality in the following terms. "The reduction of the Blue Ridge backbone to the valley level and the extension of the Plateau into the southward-flowing streams is a very rare feature. A plateau at this height, 2100 feet, moreover, is not elsewhere known south of the Blue Ridge, and its presence indicates that originally this district was tributary to the Tennessee basin. The character of Rabun Gap itself is such as to indicate that formerly an important stream flowed through it, for the rocks which occupy it are very hard and could not have been cut completely down by the present weak headwaters. The streams flowing south from the Blue Ridge are now cutting their channels with far greater speed than is the Tennessee, and have long done so. It is, therefore, reasonable to suppose that some of the headwaters of the Tennessee were captured and diverted by the swifter and more powerful streams which ran off to the south."

In addition to the evidence of diversion mentioned by Keith a few further remarks may be in place. It is true that in the Stekoa basin above and below Clayton there exist remnants of a Harrisburg level which was developed by a stream other than the Stekoa. The altitude of the former is about 2100 feet while that of the latter near its junction with the Chattooga is about 1500 feet. Furthermore, although Stekoa Creek flows to the south, the level in and around Clayton apparently slopes slightly toward the north, which is the direction of flow of the Little Tennessee River. As pointed out by Keith, the divide is low

and crossed by a valley. A few gravels also were found on the divide.

The position of the divide in Harrisburg time was probably in the dissected mountains southeast of Clayton. The gradient of the stream is very steep in that area, as is indicated by the fact that four contours are crossed in a distance of about two miles. Dick Creek, a tributary entering Stekoa Creek just below this point, developed its basin at an elevation of approximately 1500 feet as a member of the Chattooga system. Other streams east of the supposed divide have Harrisburg levels which correlate with that of the Chattooga River valley.

The head of Chattooga River is on the Blue Ridge in an open basin called Cashier Valley. In the same locality we find the source of Horsepasture and Whitewater Rivers. The heads of these three streams are in broad open basins lying along the scarp of the Blue Ridge. It is unlikely that such broad, open valleys were developed by the headwaters of the present streams, all of which now flow down the steep eastern slope of the Blue Ridge. Some of this territory probably drained originally into the French Broad, but the extent of dissection in this locality is so great that it is extremely difficult to reconstruct the former drainage lines. Detailed studies will be required to solve these local problems. Cashier Valley is a unique feature, bordered by Chimneytop, Rocky, and Whiteside Mountains.

The upper course of the Chauga River flows southwest behind distinct remnants of the Chattahoochee peneplane. In the central part of the Walhalla quadrangle it turns toward the southeast to join the Tugaloo River in the Piedmont. The direction of flow in its upper course and the presence of an almost unbroken strip of Chattahoochee surface on the east strongly suggest its former continuation toward the southwest as a member of the Chattahoochee system.

Enough has been said to indicate something of stream activity in the present cycle in the Tallulah region where streams are flowing on three different levels. The streams on the Piedmont have been attacking the Chattahoochee escarpment while those on the Chattahoochee level have been gnawing into the Blue

Ridge scarp. In addition to the cases cited there are other interesting drainage relations in this region as, for instance, at Toccoa Falls.

THE FRENCH BROAD BASIN

The headwaters of the French Broad River drain the eastern slope of the Tennessee Ridge and the western slope of the Blue Ridge in the southern portion of the Pisgah quadrangle. Other upstream tributaries of the French Broad enter from the east and flow through the Hendersonville portion of the Asheville basin. This territory is shown on the Saluda topographic map, east of the Pisgah quadrangle, and the two maps taken together portray some extremely interesting drainage relations.

In the southwestern part of the Pisgah map, the streams which rise a short distance west of the Blue Ridge flow through rather open basins and then plunge swiftly down the scarp. Lake Toxaway, a former artificial lake, now drained, is in the heart of this district. The tributaries of the Savannah have apparently deprived the French Broad of a considerable part of its former drainage basin. Reduction in volume of the French Broad is pretty definitely indicated by its misfit meanders which occur a few miles south of Brevard. The present meanders in this locality do not conform to the old meander scarps but are much smaller and the meander belt swings through the middle of the present floodplain.

In the Caesars Head area, northeast of the locality just described, the scarp is a much sharper feature and lacks the maze of spurs and remnants which are associated with its front in the Lake Toxaway area. Nevertheless, even here, there is undoubted evidence of the ravages of the easterly flowing streams in abstracting the waters of the high-lying valleys to the west. The head of Mathews Creek has pushed beyond the scarp and drains an open basin, causing a westward swing of the major divide. In like manner Middle Saluda River, a short distance to the north, has gained some of the territory of the tributaries of the French Broad.

One of the best points from which to study the extent of dis-

section of the Blue Ridge scarp by easterly flowing streams is a hilltop a short distance southwest of Saluda. From a tower, built a few years ago on this hill, one gets an unusual view. Looking toward the northwest he can see in the distance the slightly dissected Asheville peneplane as it is beautifully developed in a large area around Hendersonville. It is the least dissected of any of the larger areas of the Asheville basin. As the observer looks at the topography immediately surrounding him, however, he sees in every direction a country largely covered by forest and dissected to depths of more than 500 feet. This is, in fact, the heart of a district with almost as perfect accordance of hilltop as exists in much of the Asheville basin, but deeply dissected. This area centers around Saluda, and is approximately ten miles in width and twelve to fifteen miles in length. It differs from the Asheville basin only in its greater depth of dissection, and it joins perfectly, so far as accordance is concerned, with the undissected part of the Hendersonville surface. Its topography, however, contrasts sharply with the slightly dissected Hendersonville region.

This area is drained by the Green and North Pacolet Rivers; and master pirates they have been. In passing across this district, one finds the Green River flowing in a canyon 500 feet below the Harrisburg level. A large part of the water at present passes through giant pipe lines and is used for power. Smaller streams, such as Camp Creek, have much shallower valleys due to inability in the time since capture to cut down their beds to the level of the Green River. Hungry River, a large tributary which enters the Green from the north, has been able to carve a steep-walled canyon. North Saluda River also has pushed up from the south and played a part in the post-Harrisburg dissection of the region.

The name Blue Ridge is generally applied to the dissected country drained by the rivers previously described. In this situation it is neither a scarp nor an important divide. The main divide lies to the west and the much dissected eastern margin of the upland is to the east. In the Green River basin the dissected upper level of Harrisburg age "breaks joint" with the Pied-

mont Peneplane. It is one of the few localities where one may pass from the Piedmont Province into the Older Appalachians without encountering any remnant of the Schooley Peneplane. A rather pronounced linearity is seen in the drainage lines in this area, especially near the northern margin of the Saluda map. The trend of these lines is northeast and southwest. Green and North Pacolet Rivers, flowing to the northeast, grew by headward erosion toward the southwest, their progress being facilitated by the rock structure. The country is so badly dissected that it is next to impossible to locate any traces of the former drainage lines. A rather careful study was made along the present divide between the French Broad and Green Rivers to discover possible evidence of former channels, without much success. By virtue of its location, Mine Gap seems to be a likely situation, but the field evidence is not convincing, although it is quite possible that a former stream did have this position. There is no question about the fact that this large area once drained through the French Broad because the traces of the Asheville level at elevations of 2200 to 2250 feet are abundant.

Not satisfied with its ravages in the basin south of Hendersonville, Green River pushed on toward the southwest to collect more tribute from the French Broad by capturing some of the headwaters of Little River, east of Cedar Mountain. The evidence observed in this locality includes barbed tributaries, such as Laurel Creek, the presence of the higher erosion level at 2800 feet in the area of these barbed tributaries, and the low divide between Green River and Reasonover Creek. Definite traces of a former channel were seen on this divide in the transverse profile and stream gravels.

Green River shows, even in the Piedmont, the effects of increased volume. It has intrenched itself more deeply into the peneplane than its neighbors, and is therefore better suited for power development. The same stream south of Zirconia, in the upland area west of Saluda, flows in a mature valley because it has not yet succeeded in lowering its channel entirely across the territory which it stole from the French Broad. Still farther upstream it becomes youthful again and continues thus almost

to its head, where it has its source in the mature valleys which it took from Little River. A striking example of drainage alignment involves the valleys of Little, Green, and Hungry Rivers.

In the northern part of the Saluda quadrangle, Broad River flows southeastward through an impressive gorge by Chimney Rock into the Piedmont. The drainage in this area approaches the trellis pattern, the more pronounced trend being northeast and southwest. In the upper part of the Broad River valley, and also around Gerton there are indications of the Asheville level at an elevation of about 2500 feet. Deep dissection in this district has removed most of the traces of Harrisburg erosion. Remnants of this level in the basins of the streams and the youthful character of the Broad River gorge, shown in Plate LXIX, strongly suggest an eastern diversion of this drainage. The field evidence, however, is not very clear.

THE LINVILLE BASIN

The Linville River as represented on the Cranberry and Morganton topographic maps furnishes the most unique and certainly the most puzzling of all the drainage problems in the Older Appalachians. This stream, after flowing for twelve or fifteen miles through its open upper basin, presumably Harrisburg in age, plunges headlong over the scarp at Linville Falls. A photograph from Linville near its head shows the mature character of its upstream portion (Plate LXX). In Plate LXXI there is reproduced a view of the valley below the Falls. A strip of upland with a width of five miles and a maximum length of fifteen miles drains eastward over the scarp. It is inconceivable that this open basin was developed when the lower Linville had its present position. If diversion has occurred, a difficult question arises as to the former position of the stream.

By reference to the map it will be seen that a short distance below the Falls the Linville is flowing in a deeply intrenched meandering course down the front of the scarp. It is obvious that these meanders were developed when the stream was essentially at grade. This would require that the meandering section of the stream was once a part of the basin behind the scarp, and the capture must have taken place below the meanders.

The obvious difficulty in restoring its former lower course is the extensive dissection of the scarp. The writer at present sees no satisfactory route which the stream might have followed before piracy occurred. The sags along the northwestern divide above the Falls have been studied with some care in the hope of discovering traces of a former outlet. The surface of the Linville basin "breaks joint" with the North Toe River basin north and south of Doe Hill Mountain, the two being separated by a scarp five hundred feet in height. It is highly improbable that these two basins were developed by the same stream. The most favorable outlet above the Falls is near Montezuma, where the two basin levels on opposite sides of the divide have elevations of approximately 3800 feet. A former course to the North Toe River here might satisfy the conditions in the upper Linville basin but it would not meet the requirements of the lower basin just above the Falls where the elevation is 3200 feet. The local peneplane level of the Linville basin slopes downstream.

The downstream slope of the peneplane, the Falls and the entrenched meanders seem to indicate that the piracy occurred below the meander zone. West of Linville River there is a low sag north of Jackson Knob on the Blue Ridge behind which lies the open Harrisburg basin of the North Toe River. The broad valley of a tributary of Honeycut Creek extends northeast from this gap. This would seem to be a possible position for the Linville River, because the gap-like sag in the scarp is just a little below the level of the meander spurs previously mentioned. At the same time, this proposal would involve the crossing of the valley of North Cove Fork which is more advanced in stage of development than the Linville River. This stream may have first captured the Linville River west of Linville Mountain and later a tributary of the Catawba gnawing into the scarp diverted it east of Linville Mountain directly to the master stream. The Blue Ridge scarp is low at McKinney and Gillespie Gaps on the Mt. Mitchell quadrangle, and either may have been occupied by the ancient Linville River. The scarp in these localities is only slightly higher than the broad Harrisburg basin between Mica and Sprucepine. Owing to extensive dissection all traces of its

former valley below the meanders has apparently been erased. If piracy has occurred below the Falls, as it seems reasonable to suppose, the most plausible former course leads westward to the North Toe River.

Perhaps the intrenched meanders date from an earlier cycle, and have endured to the present because of unusually resistant rock. In this case the piracy may have taken place much earlier than the beginning of the present cycle. It is believed, however, that its upper basin bears unmistakable evidence of Harrisburg erosion. The final solution of this problem awaits further study.

A minor change in drainage may be seen where Honeycut Creek has beheaded Rose Creek. This illustrates in a small way what has been suggested for Linville River. A wind gap on the Blue Ridge scarp marks the former course of Rose Creek. Near Linville Falls, North Cove Creek has captured a basin which doubtless drained originally into Linville River. On the east side of Jonas Ridge tributaries of the Catawba River have at a number of places abstracted drainage territory from the upland.

THE HILLSVILLE AREA

Although the Blue Ridge is and has been for a long while a migrating divide, it is surprising how few well attested cases of drainage diversions have occurred. In the present study no effort has been made to point out every instance, but most of the larger and more important ones have been described. A very typical section of the scarp is shown on the Hillsville, Virginia-North Carolina, topographic map. The Atlantic streams are gnawing vigorously into the divide and have made some large re-entrants. Nevertheless, although the divide is retreating, very little evidence of capture is seen. Almost the only example on the map is in the southwestern corner where a tributary of Roaring Fork has recently added a portion of the upland to its basin. It should be pointed out, however, that active dissection of a scarp by many streams quickly destroys the upland drainage basins that are won, and consequently the evidence of capture soon disappears.

LIST OF REFERENCES

1. Abbe, Cleveland, Jr.; A general report of the physiography of Maryland. Md. St. Weather Service 1: 41-216, maps (1899).
2. Adams, G. I.; The course of the Tennessee River and the physiography of the southern Appalachian region. J. G. 36: 481–493 (1928).
3. Bowman, Isaiah; Forest Physiography. 750 pp., map, N. Y., (1911).
4. Campbell, M. R.; Tertiary changes in the drainage of southwestern Virginia. Am. J. Sc. (3) 48: 21–29 (1894).
5. Campbell, M. R.; Description of the Estillville sheet (Ky.-Va.-Tenn.). U. S. G. S., G. Atlas Estillville fol. (no. 12): 5 pp., maps (1894).
6. Campbell, M. R.; Drainage modifications and their interpretation. J. G. 4: 567–581, 657–678 (1896).
7. Campbell, M. R.; The origin of some mountain scarps (Abst.). Am. G. 17: 408 (1896).
8. Campbell, M. R.; Description of the Pocahontas sheet (Va.-W.Va.). U. S. G. S., G. Atlas Pocahontas fol. (no. 26): 5 pp., maps (1896).
9. Campbell, M. R.; The origin of certain topographic forms (Abst.). J. G. 5: 323–324 (1897).
10. Campbell, M. R.; Description of the Tazewell quadrangle (Va.-W. Va.). U. S. G. S., G. Atlas Tazewell fol. (no. 44): 6 pp., maps (1897).
11. Campbell, M. R.; Description of the Richmond quadrangle (Ky.). U. S. G. S., G. Atlas Richmond fol. (no. 46): 4 pp., maps (1898).
12. Campbell, M. R.; Description of the London quadrangle (Ky.). U. S. G. S., G. Atlas London fol. (no. 47): 3 pp., maps (1898).
13. Campbell, M. R.; Description of the Standingstone quadrangle (Tenn.) U. S. G. S., G. Atlas Standingstone fol. (no. 53): 5 pp., maps (1899).
14. Campbell, M. R.; Description of the Bristol quadrangle (Va.-Tenn.). U. S. G. S., G. Atlas Bristol fol. (no. 59): 8 pp., maps (1899).
15. Campbell, M. R.; Description of the Huntington quadrangle (W. Va.-Ohio). U. S. G. S., G. Atlas Huntington fol. (no. 69): 6 pp., maps (1900).
16. Campbell, M. R.; Description of the Charleston quadrangle (W. Va.). U. S. G. S., G. Atlas Charleston fol. (no. 72): 9 pp., maps (1901).
17. Campbell, M. R.; Description of the Raleigh quadrangle (W. Va.). U. S. G. S., G. Atlas Raleigh fol. (no. 77): 8 pp., maps (1902).
18. Campbell, M. R.; Geographic development of northern Pennsylvania and southern New York. G. Soc. Am., B. 14: 277–296 (1903).
19. Darton, N. H.; Description of the Staunton sheet (Va.-W. Va.). U. S. G. S., G. Atlas Staunton fol. (no. 14): 4 pp., maps (1894).
20. Darton, N. H.; Outline of Cenozoic history of a portion of the middle Atlantic slope. J. G. 2: 568–587, maps (1894).
21. Darton, N. H.; Description of the Franklin quadrangle (W. Va.-Va.). U. S. G. S., G. Atlas Franklin fol. (no. 32): 6 pp., maps (1896).
22. Darton, N. H., and Taff, J. A.; Description of the Piedmont sheet (W. Va.-Md.). U. S. G. S., G. Atlas Piedmont fol. (no. 28): 6 pp., maps (1896).
23. Darton, N. H.; Description of the Monterey quadrangle (Va.-W. Va.). U. S. G. S., G. Atlas Monterey fol. (no. 61): 7 pp., maps (1899).
24. Davis, W. M.; The geological dates of origin of certain topographic forms on the Atlantic slope of the United States. G. Soc. Am. B. 2: 545–586 (1891).

25. Davis, W. M.; The Blue Ridge of North Carolina. (Abst.) Science n. s. 17: 220 (1903).
26. Davis, W. M.; The Blue Ridge in southern Virginia and North Carolina. (Abst.) J. G. 11: 121 (1903).
27. Davis, W. M.; The stream contest along the Blue Ridge. Geog. Soc. Phila., B. 3: 213–244 (1903).
28. Elliott, J. B.; The age of the southern Appalachians. Am. J. Sc. (3) 25: 282–298 (1883).
29. Fenneman, N. M.; Physiographic divisions of the United States. As. Am. Geog., An. 6: 19–98, map (1917).
30. Glenn, L. C.; Denudation and erosion in the southern Appalachian region and the Monongahela Basin. U. S. G. S., P. P. 72: 137 pp. (1911).
31. Hayes, C. W.; Ringgold atlas sheet (Ga.-Tenn.). U. S. G. S., G. Atlas Ringgold fol. (no. 2): 3 pp., maps (1894; prel. ed. 1892).
32. Hayes, C. W.; Report on the geology of northeastern Alabama and adjacent portions of Georgia and Tennessee. Ala. G. S., B., 4: 85 pp., map, Montgomery (1892).
33. Hayes, C. W.; Description of the Kingston sheet (Tenn.). U. S. G. S., G. Atlas Kingston fol. (no. 4): 4 pp., maps (1894; prel. ed. 1892).
34. Hayes, C. W.; Chattanooga atlas sheet: description (Tenn.). U. S. G. S., G. Atlas Chattanooga fol. (no. 6) 3 pp., maps (1894).
35. Hayes, C. W.; Description of the Sewanee sheet (Tenn.). U. S. G. S., G. Atlas Sewanee fol. (no. 8): 4 pp., maps (1894).
36. Hayes, C. W.; Description of the Cleveland sheet (Tenn.). U. S. G. S., G. Atlas Cleveland fol. (no. 20): 4 pp., maps (1895).
37. Hayes, C. W.; The southern Appalachians. Nat. Geog. Soc., Nat. Geog. Mon. 1: 305-336, map (1895).
38. Hayes, C. W.; Description of the McMinnville sheet (Tenn.). U. S. G. S., G. Atlas McMinnville fol. (no. 22): 3 pp., maps (1895).
39. Hayes, C. W.; Description of the Stevenson sheet (Ala.-Ga.-Tenn.). U. S. G. S., G. Atlas Stevenson fol. (no. 19): 4 pp., (1895).
40. Hayes, C. W.; Description of the Pikeville sheet (Tenn.). U. S. G. S., G. Atlas Pikeville fol. (no. 21): 4 pp., maps (1895).
41. Hayes, C. W.; Physiography of the Chattanooga district, in Tennessee, Georgia, and Alabama. U. S. G. S., An. Rep. 19 pt. 2: 1–58, maps (1899).
42. Hayes, C. W.; Description of the Rome quadrangle (Ga.-Ala.). U. S. G. S., G. Atlas Rome fol. (no. 78): 6 pp., maps (1902).
43. Hayes, C. W., and Campbell, M. R.; Geomorphology of the southern Appalachians. Nat. Geog. Mag. 6: 63–126, maps (1894).
44. Johnson, D. W.; The tertiary history of the Tennessee River. J. G. 13: 194–231, map (1905).
45. Johnson, D. W.; Drainage modifications in the Tallulah district. Boston Soc. Nat'l Hist. Pr. 23: 211-248, (1907).
46. Johnson, Douglas; Stream sculpture on the Atlantic slope. Columbia University Press, New York (1931).
46a. Keith, Arthur; Geology of Catoctin belt. U. S. G. S., An. Rp. 14 pt. 2: 285-395 (1894).
47. Keith, Arthur; Description of the Knoxville sheet (Tenn.-N.C.) U. S. G. S., G. Atlas Knoxville fol. (no. 16): 6 pp., maps (1895).

48. KEITH, ARTHUR; Some stages of Appalachian erosion. G. Soc. Am. B. 7: 519–525, map (1896).
49. KEITH, ARTHUR; Description of the Wartburg quadrangle (Tenn.). U. S. G. S., G. Atlas Wartburg fol. (no. 40): 4 pp., maps (1897).
50. KEITH, ARTHUR; Description of the Maynardville quadrangle (Tenn.). U. S. G. S., G. Atlas Maynardville fol. (no. 75): 6 pp., maps (1901).
51. KEITH, ARTHUR; Description of the Cranberry quadrangle (N.C.-Tenn.). U. S. G. S., G. Atlas Cranberry fol. (no. 90): 9 pp., maps (1903).
52. KEITH, ARTHUR; Description of the Asheville quadrangle (N.C.-Tenn.). U. S. G. S., G. Atlas Asheville fol. (no. 116): 10 pp., maps (1904).
53. KEITH, ARTHUR; Description of the Greeneville quadrangle (Tenn.-N.C.). U. S. G. S., G. Atlas Greeneville fol. (no. 118): 8 pp., maps (1905)
54. KEITH, ARTHUR; Description of the Mount Mitchell (N.C.-Tenn.). U. S. G. S., G. Atlas Mount Mitchell fol. (no. 124): 10 pp., maps (1905).
55. KEITH, ARTHUR; Description of the Nantahala quadrangle (N.C.-Tenn.). U. S. G. S., G. Atlas Nantahala fol. (no. 143): 11 pp., maps (1907).
56. KEITH, ARTHUR; Description of the Pisgah quadrangle (N.C.-S. C.). U. S. G. S., G. Atlas Pisgah fol. (no. 147): 8 pp., maps (1907).
57. KERR, W. C.; Origin of some new points in the topography of North Carolina. Am. J. Sc. (3) 21: 216–219 (1881).
58. KERR, W. C.; Physiographical description of North Carolina. 32 pp., map Raleigh, N. C. (1882).
59. LAFORGE, LAWRENCE, AND PHALEN, W. C.; Description of the Ellijay quadrangle (Ga.-N. C.-Tenn.). U. S. G. S., G. Atlas Ellijay fol. (no. 187): 18 pp., maps (1913).
60. LAFORGE, LAWRENCE, COOKE, WYTHE, KEITH, ARTHUR, AND CAMPBELL, M. R.; Physical geography of Georgia; with an introduction by S. W. McCallie: Georgia Geol. Survey Bull. 42, 189 pp., 6 figs., 43 pls. (1925).
61. LUSK, R. G.; Gravel on the Highland Rim plateau and terraces in the valley of Cumberland river. J. G. 36 no. 2: 164–170 (1928).
62. MATSON, G. C.; Water resources of the Blue Grass region, Kentucky. U. S. G. S., W. S. P. 233: 223 pp., map (1909).
63. MCGEE, W. J.; Three formations of the middle Atlantic slope. Am. J. Sc. (3) 35: 120–143, 328–330, 367–388, 448–466 (1888).
64. PHALEN, W. C.; Description of the Kenova quadrangle (Ky.-W. Va.- Ohio). U. S. G. S., G. Atlas Kenova fol. (no. 184): 16 pp., maps (1912).
65. PURINGTON, C. W.; Geological and topographical features of the region about Atlanta, Ga. Am. G. 14: 105–108, map (1894).
66. RENNER, G. T.; The physiographic interpretation of the Fall Line. Geog. Rev., 17: 278–286 (1927).
67. SHAW, E. W.; Ages of peneplanes of the Appalachian Province. G. Soc. Am. B. 29: 575–586 (1918).
68. SPENCER, A. C.; The Geology of Massanutten Mountain in Virginia. Thesis, Johns Hopkins Univ. 54 pp., map, Washington (1897).
69. STOSE, G. W., (AND OTHERS); Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17: 166 pp., 22 pls. (incl.) maps, 16 fig. (1919).
70. STOSE, G. W.; Possible Post-Cretaceous faulting in the Appalachians. Geol. Soc. Am. Bull., 38: 493–503 (1927).

71. Taff, J. A., and Brooks, A. H.; Description of the Buckhannon quadrangle (W. Va.). U. S. G. S., G. Atlas Buckhannon fol. (no. 34): 4 pp., maps, (1896).
72. Ver Steeg, Karl; Wind gaps and water gaps of the Northern Appalachians, their characteristics and significance. Ann. N. Y. Acad. of Sciences. 32: 87–220 (1930).
73. Watson, T. L., and Cline, J. H.; Drainage changes in the Shenandoah Valley region of Virginia. Va. Univ., Ph. Soc. B. sc. c. I: 349–363, map (1913).
74. Weaver, W. J.; River adjustments in North Carolina. Elisha Mitchell Sc. Soc. J. 13: 13–24 (1897).
75. White, C. H.; The Appalachian river versus a Tertiary trans-Appalachian river in eastern Tennessee. J. G. 12: 34–39 (1904).
76. Willis, Bailey; Topography and structure in the Bays Mountain, Tenn. Sc. Mines Q. 8: 242–252 (1887).
77. Willis, Bailey; Round about Asheville (N. C.). Nat. Geog. Mag. 1: 291–300, map (1889).
78. Willis, Bailey; The northern Appalachians, Nat. Geog. Soc., Nat. Geog. Mon. 1: 169–202, map (1895).
79. Wright, Frank J.; The physiography of the upper James River Basin in Virginia. Va. Geol. Survey Bull. no. 11, 67 pp., 7 figs., 3 pls. (1925).
80. Wright, Frank J.; The Blue Ridge of southern Virginia and western North Carolina. Denison Univ. Bull., Jour. Sci. Lab., 22: 116–132, 4 figs., 2 pls. (1927).
81. Wright, Frank J.; The erosional history of the Blue Ridge. Denison Univ. Bull., Jour. Sci. Lab., 23: 321–344, 6 pls. (1928).
82. Wright, Frank J.; Stream piracy near Asheville, North Carolina. Denison Univ. Bull., Jour. Sci. Lab., 24: 401–406, 1 pl. (1929).

PLATE XXXIV

The Skyline of the Great Smoky Mountains between Laurel Top on the Right and Clingmans Dome on the Left, as Seen from Plott Balsams

(Courtesy Asheville Photo Service, Asheville, N. C.)

PLATE XXXV

HARRISBURG SURFACE ON OLDER APPALACHIAN UPLAND AS SEEN FROM THE HILLSVILLE-GALAX ROAD, 6 MILES NORTHEAST OF GALAX, VA.

The Schooley Peneplane is preserved on the divide to the right

PLATE XXXVI

From Sugarloaf Mountain, Saluda Quadrangle, Showing Pisgah Ridge in the Distance and the Hendersonville Part of the French Broad Basin in the Left Middle Ground

(Courtesy Asheville Photo Service, Asheville, N. C.)

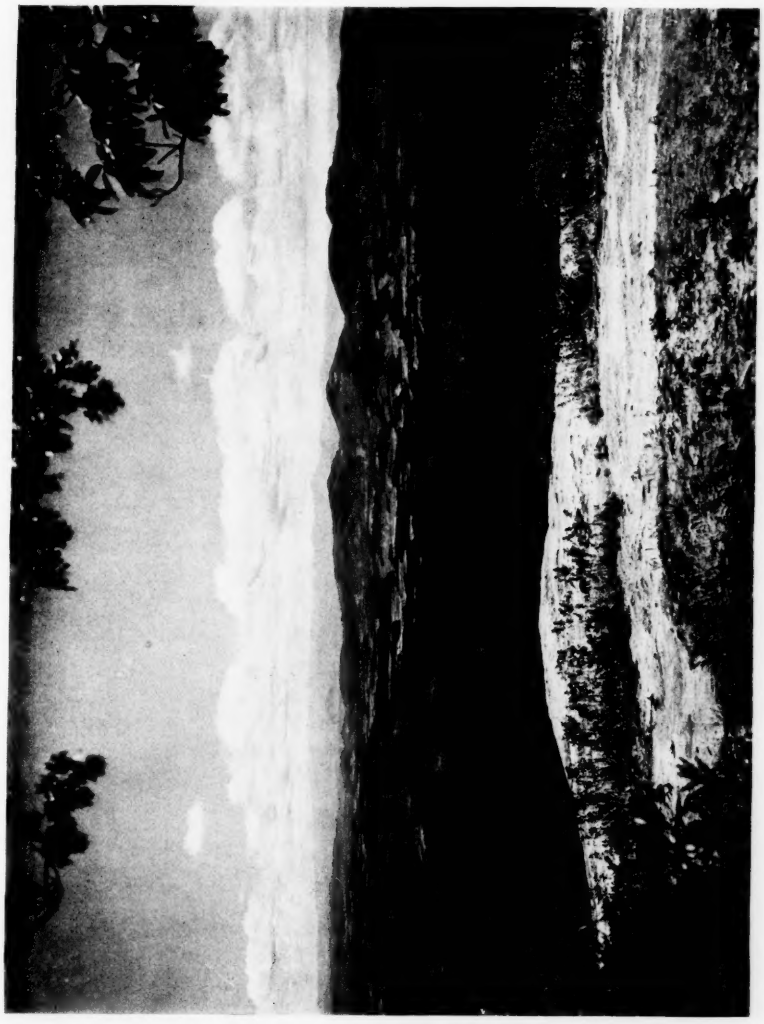

PLATE XXXVII

Mt. Mitchell (6684′) from Pinnacle on the Blue Ridge

(Courtesy Asheville Photo Service, Asheville, N. C.)

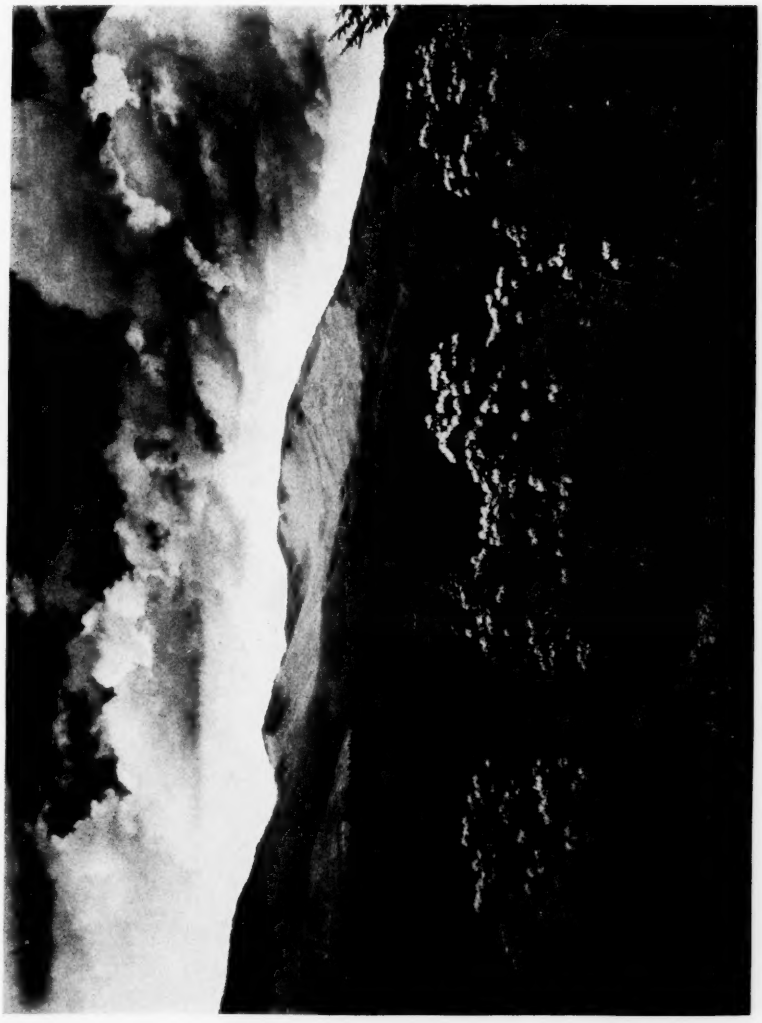

PLATE XXXVIII

GRANDMOTHER MOUNTAIN (4686′) FROM SOUTHEASTERN BASE OF GRANDFATHER MOUNTAIN

Schooley level on the left

PLATE XXXIX

BIG PISGAH MOUNTAIN (5749′) FROM PISGAH RIDGE SOUTH OF ASHEVILLE, N. C.

PLATE XL

PENEPLANED UPLAND, APPROXIMATELY 4000 FEET IN ELEVATION, WITH THE BLUE RIDGE SCARP ON THE RIGHT

From Boone Highway, six miles west of Deep Gap, N. C.

PLATE XLI

ASHEVILLE BASIN FROM WEST ASHEVILLE, N. C.

Accordant mountain tops in distance apparently represent the Schooley Peneplane.

PLATE XLII

BLUE RIDGE IN DISTANCE WITH DISSECTED HARRISBURG SURFACE IN MIDDLE DISTANCE AND FOREGROUND, FROM TOWER NEAR SALUDA, N. C.

PLATE XLIII

SCHOOLEY PENEPLANE, LOOKING WEST FROM CAESARS HEAD, S. C.

Rich Mountain, a low monadnock

PLATE XLIV

HARRISBURG BASIN OF TOCCOA RIVER, THREE MILES SOUTH OF COPPERHILL, TENN.

PLATE XLV

DISSECTED HARRISBURG LEVEL OF THE OCOEE RIVER BETWEEN DUCKTOWN AND COPPERHILL, TENN.

PLATE XLVI

NARROW FLOODPLAIN OF HIWASSEE RIVER WITH HARRISBURG HILLS BEYOND

Eleven miles northeast of Benton, Tenn.

PLATE XLVII

HIWASSEE GAP FROM THE EAST; BEANS MT. ON THE LEFT, STARR MT. ON THE RIGHT, WITH HARRISBURG COUNTRY IN FRONT OF RIDGE

PLATE XLVIII

HARRISBURG BASIN OF HIWASSEE RIVER FROM ROAD ON DIVIDE BETWEEN OCOEE AND HIWASSEE BASINS ABOUT FIVE MILES NORTH OF DUCKTOWN, TENN.

PLATE XLIX

VALLEY OF HIWASSEE RIVER ONE MILE EAST OF BRASSTOWN GAP ON ROAD TO HIWASSEE, GA.

Accordant hills in middle distance maintain the Harrisburg level

PLATE I

HORSESHOE BEND, AN INTRENCHED MEANDER OF LITTLE TENNESSEE RIVER, FROM N. C. HIGHWAY NO. 286

(Courtesy Asheville Photo Service, Asheville, N. C.)

PLATE LI

Shoal Creek Valley (Cowee Quadrangle) Just Above the Point Where the Stream Drops 400 to 500 Feet into Tuckasegee River

PLATE LII

Estatoah Falls on Mud Creek, Tributary of Little Tennessee River, on the Georgia-North Carolina Line

Mature valley above falls

PLATE LIII

HARRISBURG SURFACE ONE MILE SOUTH OF FRANKLIN, N. C., IN BASIN OF LITTLE TENNESSEE RIVER

Nantahala Mountains in background probably preserve the Schooley level

PLATE LIV

CULLASAGEE FALLS TEN MILES NORTHEAST OF HIGHLANDS, N. C., ON ROAD TO FRANKLIN

Young gorge above and below falls

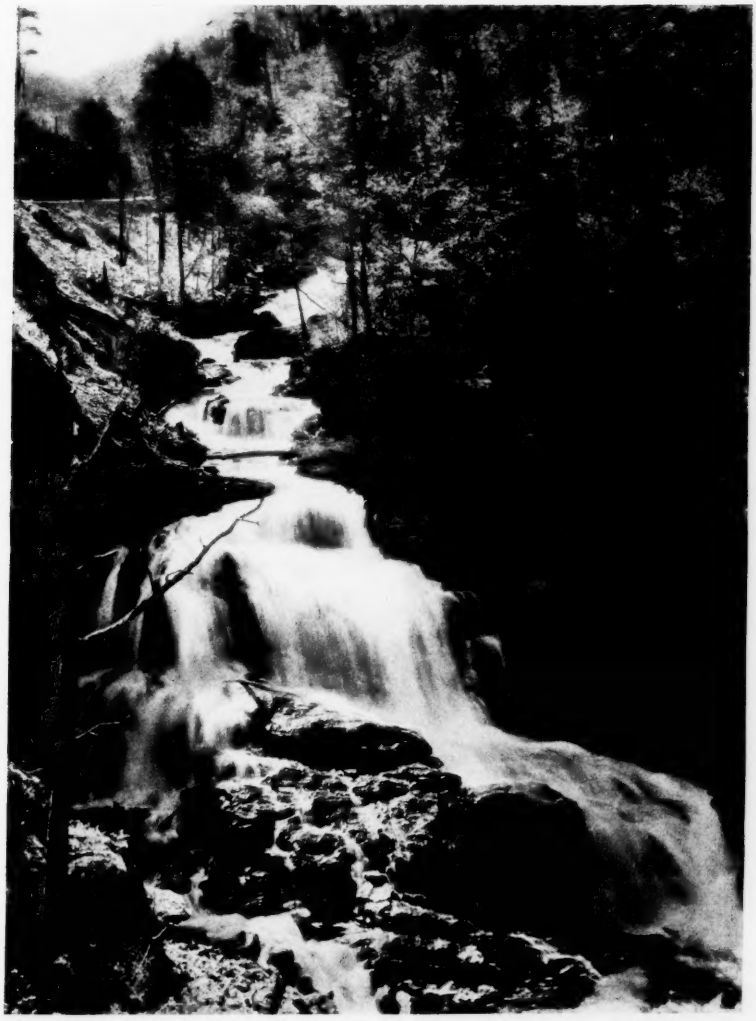

PLATE LV

BASIN OF PIGEON RIVER TWO MILES SOUTHWEST OF CANTON, N. C.

Looking toward northern rim of basin which may represent the dissected Schooley Peneplane.

PLATE LVI

BASIN OF PIGEON RIVER TWO MILES SOUTHWEST OF CANTON, N. C., LOOKING EAST

PLATE LVII

ACCORDANT HILLS IN THE VALLEY OF LITTLE CRABTREE CREEK, EAST OF BURNSVILLE, N. C.

PLATE LVIII

HARRISBURG BASIN OF SOUTH TOE RIVER FROM BASE OF LITTLE CELO MOUNTAIN, N. C.

PLATE LIX

Basin of North Toe River with Rim of Linville Basin between Mountains in the Distance

From highway four miles northeast of Sprucepine, N. C.

PLATE LX

Looking Across Linville River at Pineola, N. C.

Wooded hills maintain the Harrisburg level

PLATE LXI

Intrenched Valley of South Fork of New River Several Miles East of Boone, N. C.

PLATE LXII

Chattahoochee Escarpment from Highway Two and One-half Miles Southwest of Toccoa, Ga.

PLATE LXIII

MODERATELY DISSECTED HARRISBURG (?) PENEPLANE ONE MILE SOUTH OF HILLSVILLE, VA.

PLATE LXIV

DISSECTED HARRISBURG (?) PENEPLANE A SHORT DISTANCE NORTH OF HILLSVILLE, VA., ON ROAD TO JACKSON FERRY

PLATE LXV

CHATTAHOOCHEE LEVEL SEVEN MILES NORTHEAST OF CLARKESVILLE, GA.

PLATE LXVI

PIEDMONT FROM CHATTAHOOCHEE ESCARPMENT ABOUT FOUR MILES SOUTHWEST OF TOCCOA, GA.

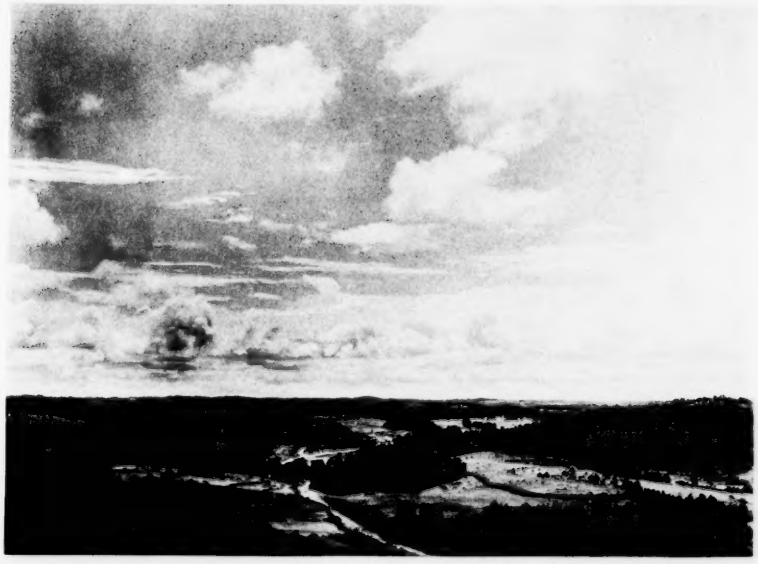

PLATE LXVII

The Intrenched French Broad River, Ten Miles Northwest of Asheville, N. C.

PLATE LXVIII

Intrenched Valley of New River West of Old Town, Va.

PLATE LXIX

Gorge of Broad River as It Leaves the Older Appalachians at Chimney Rock, N. C.

(Courtesy Asheville Photo Service, Asheville, N. C.)

PLATE LXX

MATURE VALLEY OF LINVILLE RIVER NEAR LINVILLE, N. C.

PLATE LXXI

GORGE OF LINVILLE RIVER BELOW LINVILLE FALLS

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